

2016

# Designing Infographics to support teaching complex science subject: A comparison between static and animated Infographics

Hesham Galal Hassan  
*Iowa State University*

Follow this and additional works at: <https://lib.dr.iastate.edu/etd>



Part of the [Art and Design Commons](#), [Library and Information Science Commons](#), and the [Science and Mathematics Education Commons](#)

---

## Recommended Citation

Hassan, Hesham Galal, "Designing Infographics to support teaching complex science subject: A comparison between static and animated Infographics" (2016). *Graduate Theses and Dissertations*. 15716.  
<https://lib.dr.iastate.edu/etd/15716>

This Thesis is brought to you for free and open access by the Iowa State University Capstones, Theses and Dissertations at Iowa State University Digital Repository. It has been accepted for inclusion in Graduate Theses and Dissertations by an authorized administrator of Iowa State University Digital Repository. For more information, please contact [digirep@iastate.edu](mailto:digirep@iastate.edu).

**Designing Infographics to support teaching complex science subject: A comparison  
between static and animated Infographics**

By

**Hesham Galal Hassan**

A thesis submitted to the graduate faculty  
in partial fulfillment of the requirements for the degree of

MASTER OF FINE ARTS

Major: Graphic Design

Program of Study Committee:

Paul Bruski, Major Professor

Lisa Fontaine

Kimberly Moss

Iowa State University

Ames, Iowa

2016

Copyright © Hesham Galal Hassan, 2016 All rights reserved

## TABLE OF CONTENTS

LIST OF FIGURES .....	v
LIST OF TABLES .....	vii
ACKNOWLEDGEMENTS .....	viii
ABSTRACT .....	ix
CHAPTER 1. OVERVIEW .....	1
1.1 Introduction .....	1
1.2 Definition of Key Terms .....	3
1.3 My Hypothesis .....	4
CHAPTER 2. LITERATURE REVIEW .....	5
2.1 Defining Information Graphics (Infographics) .....	5
2.2 The Nature Of Information .....	6
2.3 Information Design Principles .....	9
2.4 Static and Animated Infographics .....	18
2.5 Previous Studies On Narrated Animation And Static Infographics .....	33
2.6 What Is STEM? .....	35
2.7 Basic Education & Learning Principles .....	37
2.8 Multiple Intelligences (MI) .....	39
2.9 Information Graphics and Retention .....	43
CHAPTER 3. METHODOLOGY AND PROCEDURES .....	56
3.1 Introduction .....	56
3.2 Moon Phases Visualization Design Process .....	61
3.2.1 <i>Infographics design principles usage</i> .....	61
3.2.2 <i>The motion camera</i> .....	63
3.2.3 <i>Creating the animated format process:</i> .....	63
3.2.4 <i>Creating the static format</i> .....	71
3.2.5 <i>Creating consistency</i> .....	76
3.3 Participants .....	78

3.4 Testing Procedure .....	79
3.4.1 Test format .....	79
3.4.2 Consent form.....	80
3.4.3 Demographic form.....	80
3.4.4 Survey questions and evaluation procedures.....	81
3.4.5 Data analysis .....	83
CHAPTER 4. ANALYSIS AND RESULTS .....	84
4.1 Data.....	84
4.1.1 Data sorting.....	84
4. 2 Data Analysis & Results .....	87
4. 2.1 Overall scores .....	87
4. 2. 2 Incorrect scores .....	88
4. 2. 3 Correct scores and questions one and two advancement.....	90
4.3 Limitation of the Methodology.....	92
CHAPTER 5. CONCLUSION .....	94
APPENDIX A. IRB APPROVAL FORM.....	99
APPENDIX B. CONSENT FORM .....	100
APPENDIX C. DEMOGRAPHIC FORM .....	102
APPENDIX D. PRE TEST .....	103
APPENDIX E. PRE TEST RESULTS .....	104
APPENDIX F. POST TEST .....	105
APPENDIX G. POST TEST RESULTS .....	106
APPENDIX H. PRE AND POST TEST RESULTS (Right Answers).....	107
APPENDIX I. PARTICIPANT’S COMMENTS, POST-TEST GROUP A .....	108
APPENDIX J. PARTICIPANT’S COMMENTS, POST-TEST GROUP B .....	109
APPENDIX K. QUESTION FOUR ANSWERS .....	110
APPENDIX L. DEMOGRAPHIC DATA (GROUP A).....	111



APPENDIX M. DEMOGRAPHIC DATA (GROUP B).....	113
BIBLIOGRAPHY .....	115

## LIST OF FIGURES

Figure 1. Organizational chart of President Obama’s proposed Healthcare system.....	7
Figure 2. Charles Joseph Minard’s map 1869, Tufte, E. R. (2006).....	10
Figure 3. Detail (A) from Charles Joseph Minard’s map 1869, Tufte, E. R. (2006).....	11
Figure 4. Detail (B) from Charles Joseph Minard’s map 1869, Tufte, E. R. (2006).....	12
Figure 5. Detail (C) from Charles Joseph Minard’s map 1869.....	13
Figure 6. The use of tanned color to depict flow line of the army in Minard Map .....	16
Figure 7. “Giant Waves” .....	19
Figure 8. “New Telescopes in South America” .....	20
Figure 9. “How much water do we consume?” .....	21
Figure 10. “Mecca & the Hadsch (Haddsch, hajj, haj, hadj)” .....	22
Figure 11. “Rubik’s Cube” .....	23
Figure 12. “The sinking of the Titanic” .....	24
Figure 13. “The Great fort of Nizwa” .....	25
Figure 14. “Bee keeping in Oman” .....	26
Figure 15. First layout for the two-pages spread info-graphic, “Bee keeping in Oman” ..	27
Figure 16. “Traditional Oman Dress (Male)” 2015.....	28
Figure 17. “Oman’s National Dress (Male)” 2015.....	29
Figure 18. Captures from National Geographic Magazine Interactive version .....	31
Figure 19. Captures from National Geographic Magazine Interactive version .....	32
Figure 20. The most common pre-attentive attribute (Color & Shade).....	47
Figure 21. The most common pre-attentive attribute (Color & Shade).....	48
Figure 22. (Tapping the Power of Visual Perception, 2004, Stephen Few) .....	49
Figure 23. The Moon Phases by <a href="http://www.moonphases.info">www.moonphases.info</a> .....	57
Figure 24. Phases of The Moon by <a href="http://www.spaceplace.nasa.gov">www.spaceplace.nasa.gov</a> , .....	57
Figure 25. Captures from “Lunar Cycle, Why The Moon Change Shapes, .....	59
Figure 26. Captures from “Animation of Phases of the Moon” .....	60
Figure 27. Eight Phases of the Moon Poster, designed by the author .....	62
Figure 28. First attempt animation storyboard.....	64
Figure 29. First attempt animation final renders.....	65

Figure 30. Second animation storyboard .....	66
Figure 31. Waxing Crescent phase “space view” .....	67
Figure 32. Waxing Crescent phase “viewer-on-earth” point of view .....	67
Figure 33. Full Moon phase: “space view” .....	68
Figure 34. Full Moon Phase: “viewer-on-earth” point of view .....	68
Figure 35. Second and final animation, final renders .....	69
Figure 36. Second and final animation, final renders continue .....	70
Figure 37. First version of the “Static Format” .....	72
Figure 38. Second version of the “Static Format” .....	74
Figure 40. Final design of the “Static Format” .....	75
Figure 39. “Half Moon” Phase number 3 and “Third Quarter” Phase number 7 .....	77
Figure 41. The pre-test survey questions 1-3 .....	82
Figure 42. The post-test survey questions 1-3 .....	82
Figure 43. Question number four (Post-test survey) .....	89

**LIST OF TABLES**

Table 4.1 Group A (Animated Format) results.....	85
Table 4.2 Group B (Static Format) results.....	86
Table 4.3 Pre and Post Test scores for both groups A and B.....	87
Table 4.4 Post-Test Groups A and B Incorrect Answers.....	88
Table 4.5 Post-Test Groups A and B Correct Answers .....	90

## ACKNOWLEDGEMENTS

I would like to thank my mother who passed away while I have been far away from her side pursuing my postgraduate studies and writing this thesis for devoting her entire life to support and love her sons, without her I would not have been writing this.

My wife, who encouraged and supported me to pursue my MFA degree, I could not have realized my potential without her complete devotion and support for our little family during my study, long days and nights.

Paul Bruski, my major professor for his guidance and help during the creation of this thesis, and for his support and recommendations in my professional work.

Lisa Fontaine, for her informative guidance and teaching during both the process of this thesis and all of my postgraduate study years.

Kimberly Moss, for her immediate acceptance to be on my committee and for her crucial guidance to my work and writing, without her professional experience and knowledge this would not have been possible.

In addition, I would also like to thank Bev Krumm for her beautiful spirit and willingness to support without hesitation and the time she devoted for helping me while writing this thesis.

## ABSTRACT

This thesis explores the proper principles and rules for creating excellent infographics that communicate information successfully and effectively. Not only does this thesis examine the creation of Infographics, it also tries to answer which format, Static or Animated Infographics, is the most effective when used as a teaching-aid framework for complex science subjects, and if compelling Infographics in the preferred format facilitate the learning experience. The methodology includes the creation of infographic using two formats (Static and Animated) of a fairly complex science subject (Phases Of The Moon), which were then tested for their efficacy as a whole, and the two formats were compared in terms of information comprehension and retention. My hypothesis predicts that the creation of an infographic using the animated format would be more effective in communicating a complex science subject (Phases Of The Moon), specifically when using 3D computer animation to visualize the topic. This would also help different types of learners to easily comprehend science subjects.

Most of the animated infographics produced nowadays are created for marketing and business purposes and do not implement the analytical design principles required for creating excellent information design. I believe that science learners are still in need of more variety in their methods of learning information, and that infographics can be of great assistance. The results of this thesis study suggests that using properly designed infographics would be of great help in teaching complex science subjects that involve spatial and temporal data. This could facilitate learning science subjects and consequently impact the interest of young learners in STEM.

## **CHAPTER 1. OVERVIEW**

### **1.1 Introduction**

Infographics design has been a recent popular design and visualization tool preferred by many clients and designers alike to communicate their messages in a visually interesting and engaging style while providing important data and information. However, today's work is not always meeting the standards of what proper data and information design should be. Precedents created by renowned designers and scientists have already used information design and visualization techniques since the last century to document and visualize crucial information and events. They were able to create masterpieces of information and data designs that achieved excellence in terms of being unique & visually appealing, containing compelling data, and communicating the intended message clearly.

Numerous authors wrote about information graphics principles and why those rules work perfectly in communicating the information successfully and increasing the retention of data. Research and studies from a cognitive psychological point of view indicates that information and data presented through the implementation of information design theories and principles are more likely to achieve higher comprehension and retention rates.

Teaching a complex science subject like astronomy has been a challenge for both teachers and education pedagogues. Many students find it hard to comprehend heavy spatial and temporal data at various school stages. A complex science subject (Example: Phases Of The Moon) that involves spatial and temporal data was chosen as the topic for the creation of an animated infographic that explains the Moon Phases phenomenon.

The literature review provides a foundation for what defines the principles and rules for the creation of successful information design projects. There are known to be cognitive benefits of using infographics in communicating data and information, because the human brain recognizes data within the infographics effectively. Moreover, the findings will help designers and educators to determine the proper and best solutions for creating teaching-aid frameworks for communicating complex science subjects. To evaluate the efficacy of infographics in teaching complex science subjects, educators need to know which medium (Static or Animated) is more effective than the other to present the information. Static and Animated infographic formats will be tested and compared to determine the best solution for teaching this subject, along with how this format could be implemented for future creation of infographic-based teaching-aid frameworks that support, advance and facilitate the learning process and consequently improve and increase the percentage of students in the STEM field. According to the Multiple Intelligence Theory and Neil Flemings's VAK Model there are different types of learners, some of which may face difficulties studying STEM subjects due to their own learning style or intelligence (Visual learners and Image Smart people). Therefore, infographics have the potential of being a valuable learning tool for them. This should advance the learning curve and help future students to comprehend complex science (STEM) related topics easily through a less stressful and visually interesting medium (Infographic) than text only, consequently increasing information retention. Information comprehension and retention are the most demanded objective from any successful teaching process.



## 1.2 Definition of Key Terms

Many terms included in this thesis are widely used in today's informal and formal communication. However, they still appear as misspelled words in some word processing applications. For justifications on this thesis the following key terms are:

- **Infographics:** “Infographics stand for visual displays in which graphics (illustrations, symbols, maps, diagrams) together with verbal language communicate information that wouldn't be possible otherwise.” (Meirelles, I. 2013).
- **Information Design:** “Is broadly used to describe communication design practices in which the main purpose is to inform, in contrast to persuasive approaches more commonly used in practices such as advertising. **Infographics** is one of the possible outputs within the large information design discipline” (Meirelles, I. 2013).
- **Static Infographics:** Any infographics as defined above, designed with the intention for printing use (Posters, diagrams accompanying magazine articles or newspapers, and within advertisements, etc.) or digital use (in websites or for screen views like digital displays) without the inclusion of any movement or animated elements or features.
- **Animated Infographics or Motion Infographics:** Any infographics as defined above, designed with the intention for a screen playing view and displays (Motion graphics videos: in video websites like YouTube & Vimeo, TV commercials, museum displays and kiosks, etc.) where the elements are usually in constant motion and the data in an animated form. The motion or movements are usually created using computer animation software.
- **Interactive Infographics:** Same as the Animated Infographics with the addition of interaction elements like slide bars and play buttons or any other advanced

controlling features. These gestures, used in Pads and Mobile phones, enable the viewers to play, move forward, stop, repeat or reveal specific information, data or motion from the display according to their preference for a much more engaging and informative experience.

- **Data Visualization:** Any visual representation of data that helps in the recognition of multiple trends, patterns and relations that can be difficult to comprehend and detect in traditional presentations of pure text and figures. The use of statistical graphs, **infographics**, charts and tables are crucial elements in effective data visualization in order to support reasoning and data analysis.

### 1.3 My Hypothesis

Does an animated dynamic infographic accompanied with narration help students to learn spatial and temporal science subjects more effectively than a static printed infographic containing annotated illustrations and diagrams? My hypothesis predicts that the animated format will be better at communicating the complex scientific topic mainly because the animated graphics provide a visual solution to perceive the moon phases from two different perspectives continually without breaking the viewer's line of sight. The static format has a deficiency that is providing two different perspectives of each moon phase simultaneously, which causes confusion in moon phase recognition. This hypothesis is tested using infographics that demonstrate the "Phases of the Moon."

According to Narayanan & Hegarty (2002) animated media could be effective for visualizing specific types of invisible processes, like in air dynamics research when there is a need to show how air pressure flows around birds and airplane wings.

## CHAPTER 2. LITERATURE REVIEW

### 2.1 Defining Information Graphics (Infographics)

Graphic Designers and visual communicators refer to the use of illustrations, graphs, maps, 3D modeling, icons & symbols in conjunction with data and text as Information Graphics or Infographics. Infographics is the most common term used to refer to the topic and will be used here out to avoid any misunderstanding by the graphic design community. Information graphics could be categorized under a much larger term that defines all types of designs, which involves the using of a large amount of data and information to create well structured and an easy to comprehend visuals. The larger term is **Information Architecture** where Information design falls below as a subcategory and **infographics** is a subcategory under information design.

Prof Meirelles states “Infographics stand for visual displays in which graphics (illustrations, symbols, maps, diagrams) together with verbal language communicate information that wouldn’t be possible otherwise.” (Meirelles, I. 2013)

Alberto Cairo says, “Imagine information architecture as a big circle. Inside is the set of disciplines devoted to dealing with information. Among the most relevant disciplines is information design, defined by Stanford University’s Robert E. Horn as “the art and science of preparing information so that it can be used by human beings with efficiency and effectiveness.” The goal of the information designer is to prepare documents (both analog and digital) and spaces so they can be navigated effortlessly” (Cairo, 2013).

## 2.2 The Nature Of Information

Joel Katz (Katz, 2012) categorized information into five different types:

Information

Un information

Non-Information

Misinformation

Disinformation

**Information:** Which is true and crucial for our needs. This is what we should be conveying through creating clear designs that easily communicate the information or data and sends the right message.

“**Un information:** is stuff that is not necessarily important and that probably is not untrue. Within uninformation is where the designer plays and dances. Within uninformation is **noninformation**, which is often uninformation, appearing to be information. **Misinformation** is stuff masquerading as information that is likely to distort, confuse, and mislead (and possibly injure, maim, kill). Misinformation is not necessarily deliberate but may be the result of unintentional incompetence, noncurrent data, or failure to correctly interpret source data. At the nadir of misinformation is **disinformation** (from the Russian dezinformatsiya), disinformation deliberately used to achieve a financial, political, or military objective.” (Katz, 2012)

An example of Misinformation design is the (Organizational chart of the President’s Obama’s proposed Healthcare system) (Figure 1), which released by the Republican side of the joint economic committee on 28 July 2010.

The main purpose of the chart was to convey that Obama's ACA system is too complex to be easily understood, thus it looks like it will not work successfully and it does not deserve a chance.

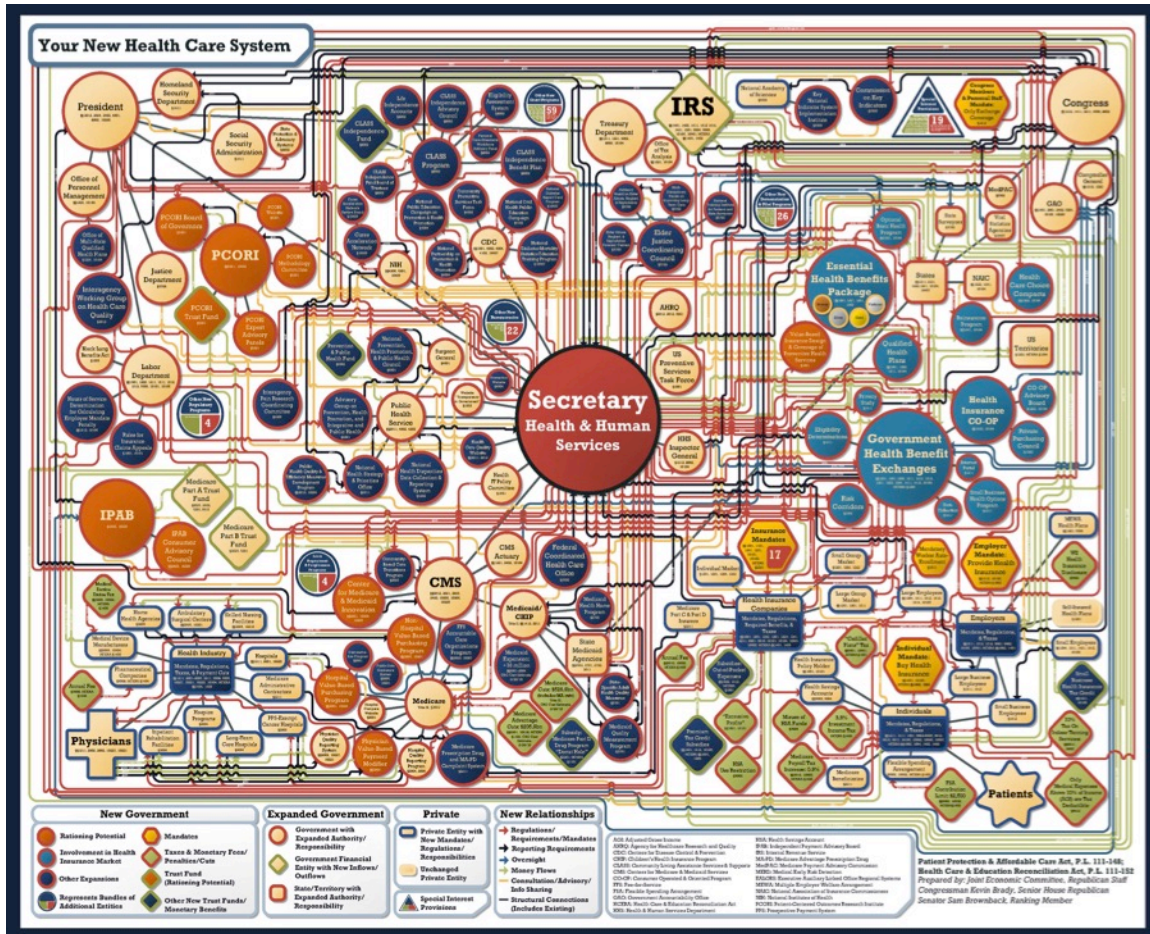


Figure 1. Organizational chart of President Obama's proposed Healthcare system. Released by the Republican side of the joint economic committee on 28 July 2010.

**Disinformation:** Examples of disinformation design exists in the explanatory illustrations and technical drawings used to illustrate illusions and magic tricks performed by magicians and illusionists, which work as a tutorial for learning and practicing the routines required to perform the illusions successfully. Usually, those illustrative instructions reveal both the front view (what the audience perceives to be done) and the

back view (what was concealed from the audience and actually completed), the disinformation part.

“To create illusions is to engage in disinformation design, to corrupt optical information, to deceive the audience”. (Tufte, 1997)

Moreover, another example of disinformation or “Propaganda” can be found through the techniques used in portraying the news in journalism and media to control the audience’s mind by providing partial facts or a completely wrong, misleading stories and lies. Prof. Noam Chomsky in his book on Media Control states how the government of the United States during the presidency of Woodrow Wilson was able to transform the peaceful American population at the time into a neurotic, war-advocacy population within six months through the use of disinformation. This was achieved by providing the media with fictional stories and lies about the war and atrocities done by the enemy. Moreover, by publishing the same exact completely misleading news stories and lies about the war in all-national and local newspapers simultaneously in order to support their claims and ensure its rightness.

“In fact, it has long been, not just in operation, but even in theory. There's a long history that goes back to the earliest modern democratic revolutions in seventeenth century England, which largely expresses this point of view. I'm just going to keep to the modern period and say a few words about how that notion of democracy develops, and why and how the problem of media and **disinformation** enters within that context.” P10 (Chomesky 2002).

## 2.3 Information Design Principles

Trying to define what is or what could be considered, as *information design principles*, would lead to a huge number of topics and rules that all relate to the Visual Communication field and Gestalt psychology. Nevertheless, Prof. Edward Tufte mentioned six different principles and called them “*Fundamental Principles of Analytical Design*” where we can consider it being part of a larger set of information design rules.

**Principle 1: Comparisons, show comparisons, contrasts and differences**

**Principle 2: Show Causality, Mechanism, Structure and Explanation**

**Principle 3: Multivariate Analysis**

**Principle 4: Integration of Evidence**

**Principle 5: Documentation**

**Principle 6: Analytical presentations ultimately stand or fall depending on the quality, relevance and integrity of their content**

Integrating those principles with other visual communication rules would definitely create successful information and graphics displays.

“Excellent graphics exemplify the deep fundamental principles of analytical design in action. If this were not the case, then something might well be wrong with the principles” (Tufte 2006)

Tufte considered Minard’s map (Figure 2) as an excellent graphic example to show his principles. The map, which was created by the French engineer Charles Joseph Minard in 1869, shows how the French army kept losing soldiers dramatically along the invasion campaign on Russia in 1812. Tufte claims it is one of the best statistical graphics ever

because of its clear historical content and clean simple design, so why is the map brilliant? Tufte described how the map is considered a role model for listing his fundamental principles of analytical design and identified each principle and its presence and application on the design of Minard's map.

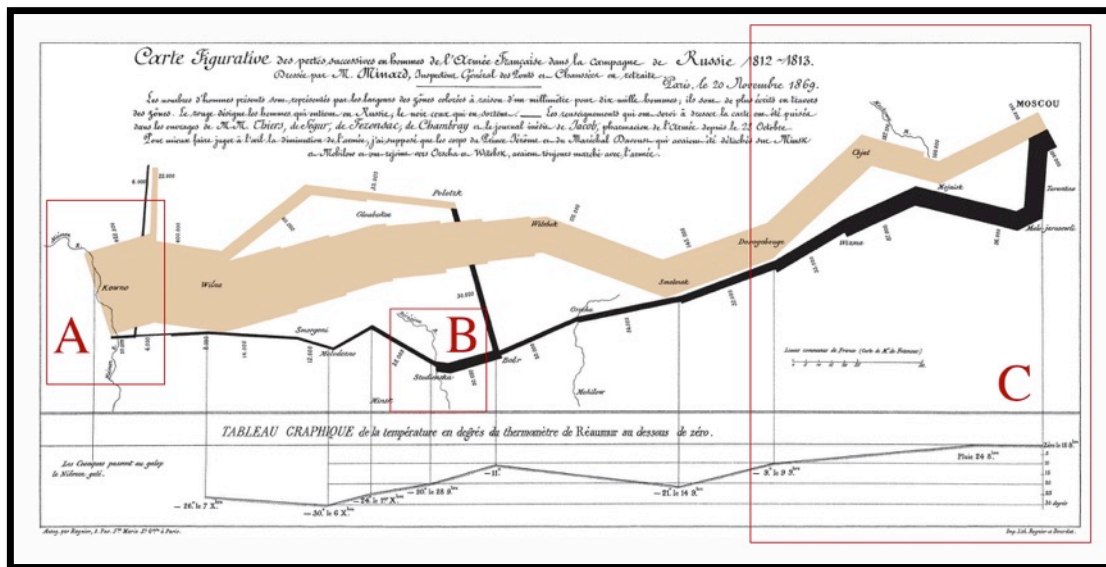


Figure 2. Charles Joseph Minard's map 1869, Tufte, E. R. (2006). Beautiful Evidence. Graphics Press LLC

### Principle 1: Comparisons show comparisons, contrasts and differences.

One of the main reasons of creating visual display is to assist thinking and to do that we should show comparison and contrast.

*"The fundamental analytical act in statistical reasoning is to answer the question "Compared with what?" Whether we are evaluating changes over space or time, searching big data bases, adjusting and controlling for variables, designing experiments, specifying multiple regressions, or doing just any kind of evidence based reasoning, the essential point is to make intelligent and appropriate comparisons" (Tufte 2006).*



Minard was able to display more than one comparison in the map that took place over different time periods.

*The First:*

The first contrast on Minard's map clearly appears at the spot on the Nieman River where the army started moving toward Russia with 422,000 soldiers. A large, wide, light brown flowing line represented the starting figure, which is in stark contrast to the very thin, black line which represented the remaining number of soldiers, only 10,000, that were able to return from the invasion and cross the Nieman river again (Figure 3). The clear visual contrast at the river spot states in a simple graphic line the fatal decrease of the army over 6 months.

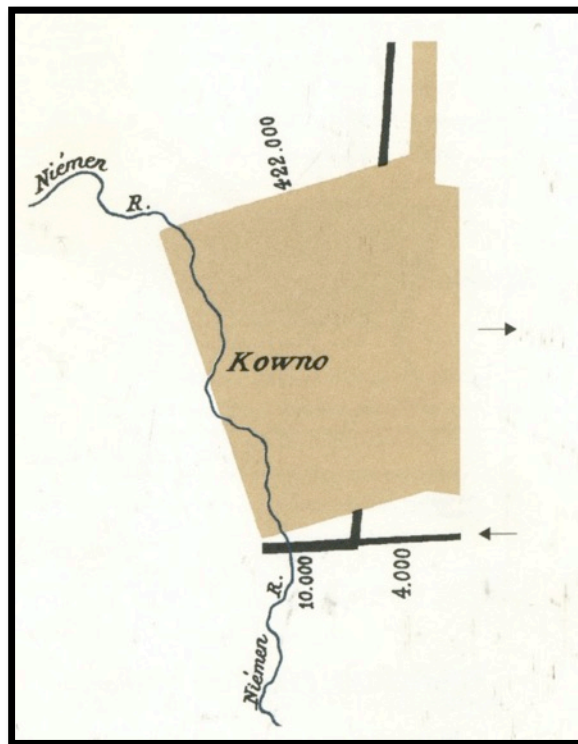


Figure 3. Detail (A) from Charles Joseph Minard's map 1869, Tufte, E. R. (2006). Beautiful Evidence. Graphics Press LLC

*The Second:*

Another comparison that took place in two days, rather than months, appears in the sudden transition of the black stroke crossing the Berezina River. The figures printed on the map show that 50,000 soldiers dropped to 28,000 just after crossing the river (Figure 4). The change in the stroke width visualizes the tragic incident in seconds. Nowadays, the word Berezina is synonymic to disaster in the French language, depicting how horrible the event truly was.

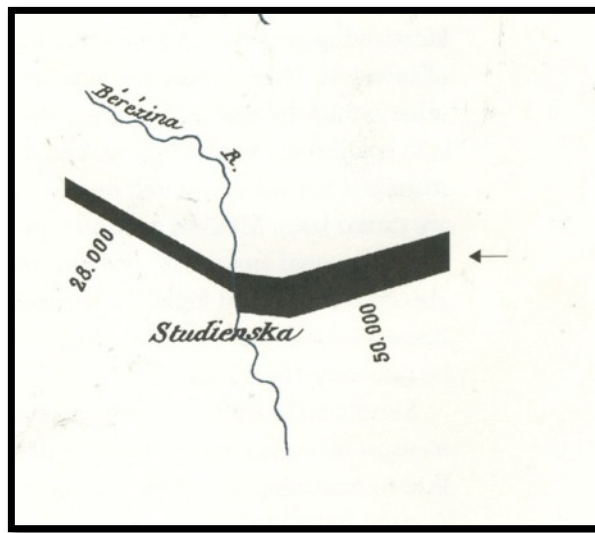


Figure 4. Detail (B) from Charles Joseph Minard's map 1869, Tufte, E. R. (2006). Beautiful Evidence. Graphics Press LLC

**Principle 2: Show causality, mechanism, structure and explanation.**

Though Minard's map shows magnificent comparisons and huge death toll numbers, we still do not know what causes those casualties. Thus, an explanation is important to support reasoning of the comparison. Tufte describes how Minard integrated a graph with the map, showing variable temperatures across multiple dates during the return journey

where most of loss took place. The temperatures on the graph serve as a possible cause of death, particularly as it shows severe low temperatures during this winter (Figure 5). Moreover, time and dates accompany the temperatures, adding another variable to support the explanation of what caused the soldiers' deaths and to relate the numbers of casualties with the severe temperatures at the time.

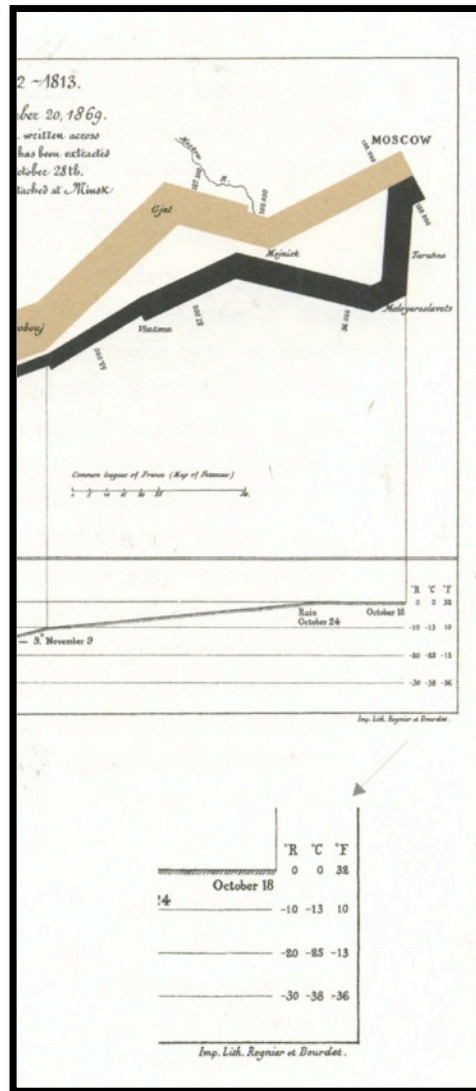


Figure 5. Detail (C) from Charles Joseph Minard's map 1869  
 (English translation version), Tufte, E. R. (2006). Beautiful Evidence. Graphics Press LLC

### **Principle 3: Multivariate analysis.**

Tufte said that Minard described the French army march to invade Russia by six different variables, however I believe there are only five variables unless he considers a location defined by Latitude & Longitude as two separate variables.

- 1- The army size (number of soldiers when the invasion journey starts and ends)
- 2- The Army location during the invasion (Latitude & Longitude).
- 3- The direction of the army's movement.
- 4- Temperatures as they were shown only during the return journey and signifies its contribution to the soldiers' deaths.
- 5- Different dates during the retreat from Moscow linked to temperature as well.

Those 5 variables were perfectly and simply displayed without any need for further copy text explanation or data.

Apart from the Napoleon's invasion of Russia map, which is clearly multivariate (as it involves three or more variables) "nearly all the interesting worlds (Physical, biological, imaginary, human) we seek to understand are inevitably multivariate in nature" (Tufte 2006).

Tufte adds, "Reasoning about evidence should not be stuck in two dimensions, for the world we seek to understand is profoundly multivariate" (Tufte 2006).

### **Principle 4: Integration of evidence.**

Tufte continue to explain that evidences should be integrated together seemingly in order to improve communication and inform successfully. Thus, a descriptive text, illustrations of maps or objects, and statistical graphs are all presented in Minard's map.

Note: This recalls the definitions of what Infographics means today:

An Infographic is simply the organizing of a collection of different types of graphics (illustrations, maps, graphs, icons, symbols) and textual information (Numbers, Names, copy text) where all together communicate an event or process that could not be conveyed otherwise.

The most obvious parts to show this integration appears across different elements on the map:

- 1- The Niemen River where the army started moving shows the number of troops beginning at 422,000 and ending at 10,000.
- 2- The flow lines depicting the number of troops across the map space by showing the thickness and weight of line decreasing as the soldiers die along the road.
- 3- The statistical graph which shows decreasing temperatures along the return trip, connecting this with locations and events.
- 4- Textual description of various events during the journey like: (The Russian Cossack Horseman pass the frozen Niemen River at a gallop) where he describes how the horsemen crossed the river.

Comparing this integration of various information types in a single two-dimensional design, to what we could have in a plain similar, only textual explanation of the invasion proves the excellence of Minard's Integration work.

“Contrast this graceful integration with books where all the images are collected into one big pile, printed and positioned far from their relevant text. Or those awful reports consisting entirely of words, except for all the data tables segregated and appended at the back, in organizational and intellectual disarray” (Tufte 2006).

In addition to learning the principle of (Integration) from the map, Minard also provided visual design solutions to layout and integrate all the elements in an aesthetically pleasing and eligible design. The use of a light, tanned color to depict the flow line of the army, allowed adding the place names over the flow line (Figure 6) with the same black ink used in other location names and numbers printed outside the flow line boundaries.

Moreover, all the place names were printed using *Italic Style*, in order to emphasis that all the names belong together to one group (Locations on the map). These solutions helped in keeping coherence across the map, while conveying a visual pleasing look and feel.

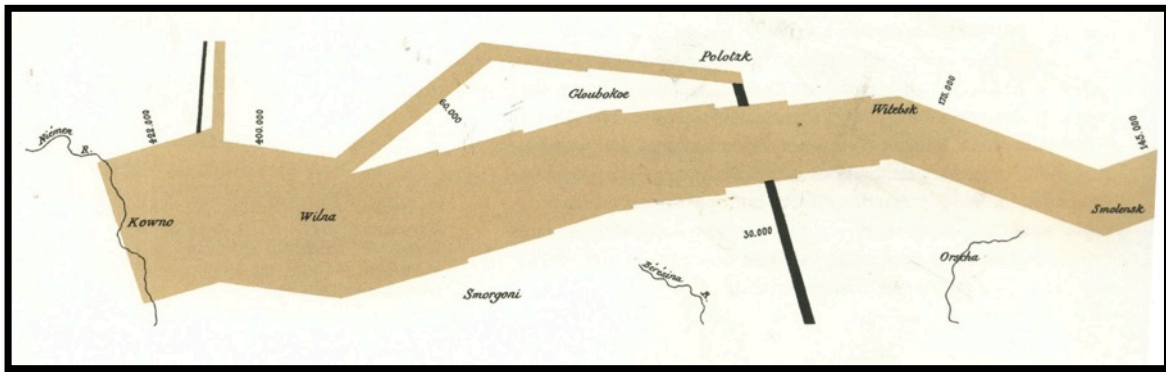


Figure 6. The use of tanned color to depict flow line of the army in Minard Map

### Principle 5: Documentation.

Creating infographics without citing the data sources and information is like drawing a kid's first sketch, only to be appreciated by his parents. In order to gain credibility for any evidence visualizations, designers should document and proof their sources, showing that they come from authentic references and integrate perfectly with the evidence.

Minard documented his map in a very high level of accuracy and detail, comparing to the standards at the time. He documented every single data he presented and gave explanation when needed to all elements as much as he could in order to make it clear

and easy to comprehend. His detailed documentation appears, as explained by Tufte (Tufte 2006), in the answers of the following questions:

*“1- What is the display about? Loss in men of the French army in the Russian campaign 1812-1813*

*2- Who did the work? Drawn up by M. Minard.*

*3- Who’s that? Inspector General of Bridges and Roads in retirement.*

*4- Where and when was the work done? Paris, November 20, 1869*

*5- What are the data sources? The information, which has served to draw up the map, has been extracted from the works of M. M. Thiers, of Segur, of Fezensac, of Chambray, and the unpublished diary of Jacob, pharmacist of the army since October 28th.*

*6- Any assumptions? In order to better judge with the eye the diminution of the army, I have assumed that the troops of Prince Jerome and of Marshal Davoush, who had been detached at Minsk and Moghilev and rejoined around Orcha and Vitebsk, had always marched with the army.*

*7- What are the scales of measurement? For invasion and retreat flow-lines: One millimeter for every ten thousand men.*

*For the temperature: degrees of the Reaumer thermometer below zero*

*8- Who published and printed the work? Autog. Par Regnier, 8. Pas. Ste. Marie St. Gain. Paris.” (Tufte 2006).*

**Principle 6: Analytical presentations ultimately stand or fall depending on the quality, relevance and integrity of their content.**

Simply, this last principle advocates quality over quantity, which means that in order to create proper and successful information graphic design or event visualizations, content quality and integrity is the crucial part. Knowing that applying graphic effects, vivid colors or decorative elements will not create excellent content from poor data.

## **2.4 Static and Animated Infographics**

Before talking about today's presence of infographics, we cannot miss the renowned historical scientific illustrations of Leonardo da Vinci work in this field. Leonardo used an intense amount of words, drawings and diagrams, which explained and clarified scientific evidence and reasoning in a brilliant style. His work proved to be of a great help in teaching science subjects at the time.

With the rapid expansion of the use of infographics in the visual communication scene today, educators, designers and visual communicators are striving to develop more interesting types of infographics in order to attract more viewers and engage them with the content. This is usually achieved by creating a visual interest in the regular static infographics. The implementation of visually interesting elements, whether it is an illustration or computer generated three-dimensional diagram or many other previously mentioned information formats, design principles create the successful formulas that make an infographic more appealing to the audience and help in communicating an intense amount of data in an easy-to-comprehend format. Examples of successful static infographics appear in the work of renowned information designers, educators and publishers like: Alberto Cairo's static designs "Giant Waves" (Fig 7) and "New



Telescopes in South America” (Fig 8). Jan Schwochow (Golden Section Graphics) “How much water do we consume?” (Fig 9) & “Mecca & the Hadsch (Hajj)” (Fig 10). Raúl Camañas “Rubik’s Cube” (Fig 11) & “The Sinking of the Titanic” (Fig 12). Antonio Farach “The Great Fort of Nizwa” (Fig 13) & “Bee Keeping in Oman” (Fig 14) & (Fig 15). Times of Oman newspaper giant Infographic “Oman’s National Dress - Male” (Fig 16) & (Fig 17).

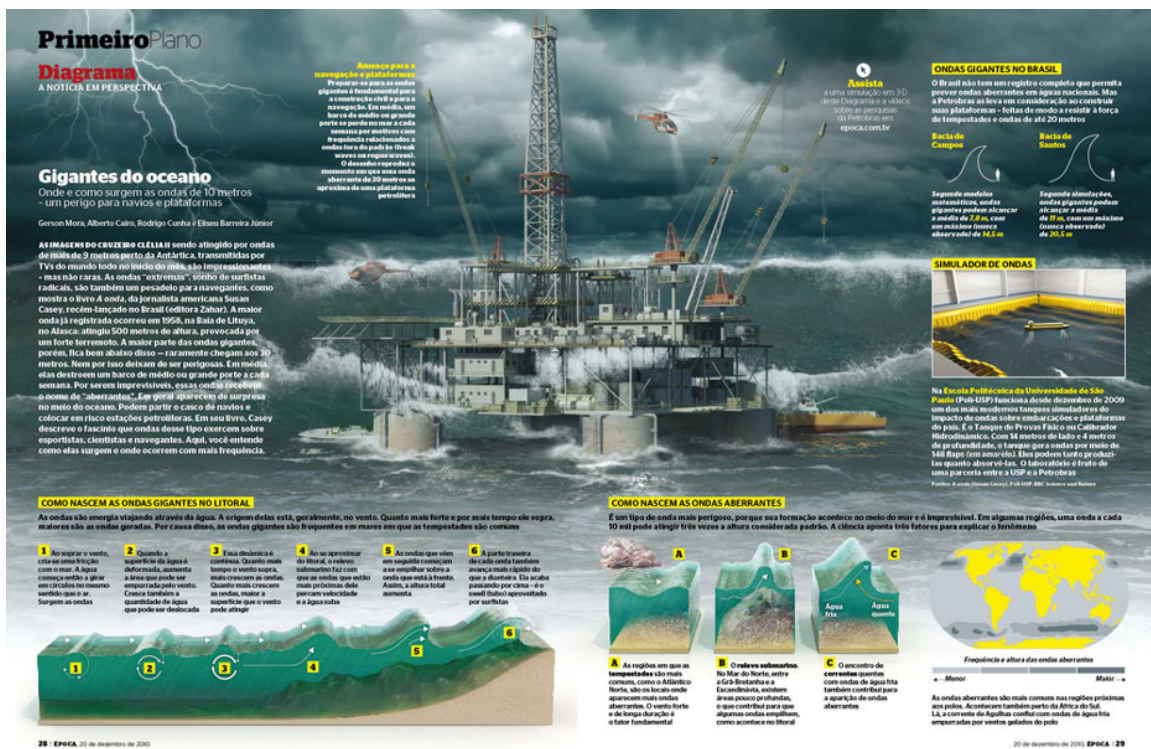


Figure 7. “Giant Waves”

For Epoca magazine by Alberto Cairo, translated from Portuguese. 2013, The Functional Art: An introduction to information graphics and visualization. New Riders.

This infographic visually describes how the giant waves form. Image dominance is not only aesthetically pleasing but also serves to show scale (Showing the comparison between helicopter, oil platform and wave size) In addition, surrounding annotated illustrations support the wave building process and provide spatial information.

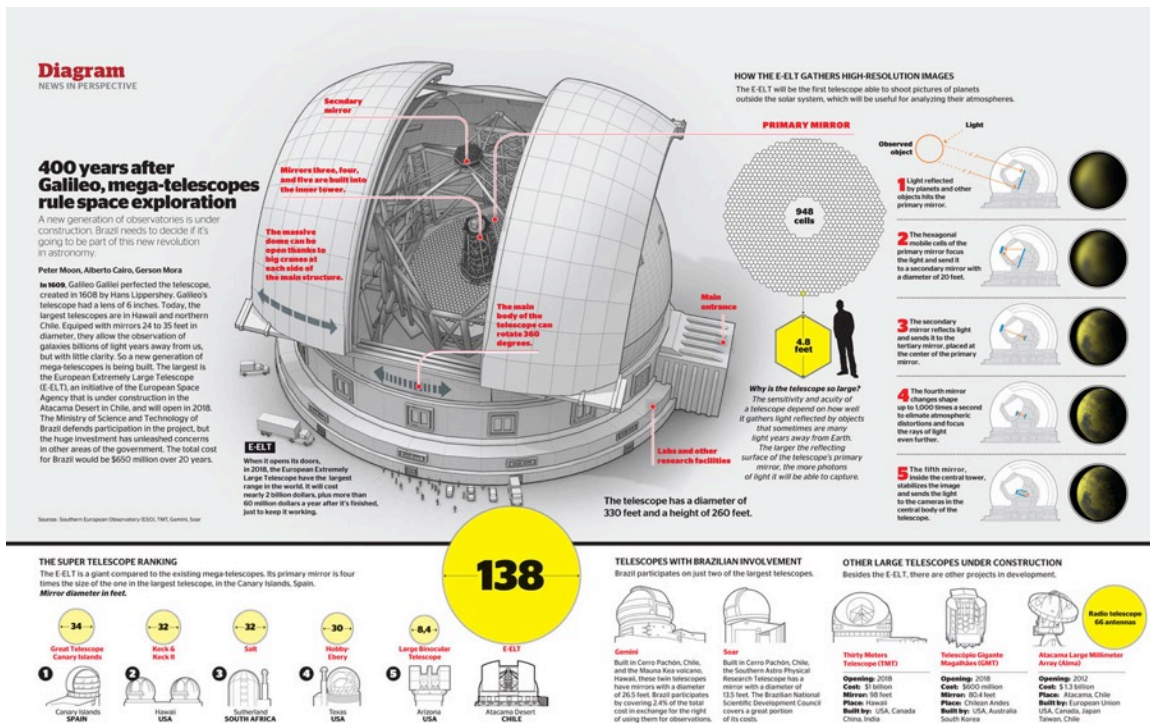


Figure 8. "New Telescopes in South America"

For Epoca magazine by Alberto Cairo and others, translated from Portuguese. 2013, The Functional Art: An introduction to information graphics and visualization. New Riders.

This Infographic explains how the mega-telescopes work and how they gather high-resolution images. Image dominance is not only aesthetically pleasing but also serves to show scale (Showing the comparison between vehicle sizes and the mega-telescopes. In addition, surrounding annotated illustrations provide extra technical information.

01

Thema:  
Umwelt

# Wie viel Wasser verbrauchen wir?

Aus der Leitung im Haushalt entnehmen die Deutschen seit den achtziger Jahren immer weniger Wasser. Doch viel größere Mengen verschlingt die Herstellung unserer Konsumgüter. In denen steckt sogenanntes »virtuelles Wasser« – und das stammt oft aus Ländern, in denen Wassermangel herrscht

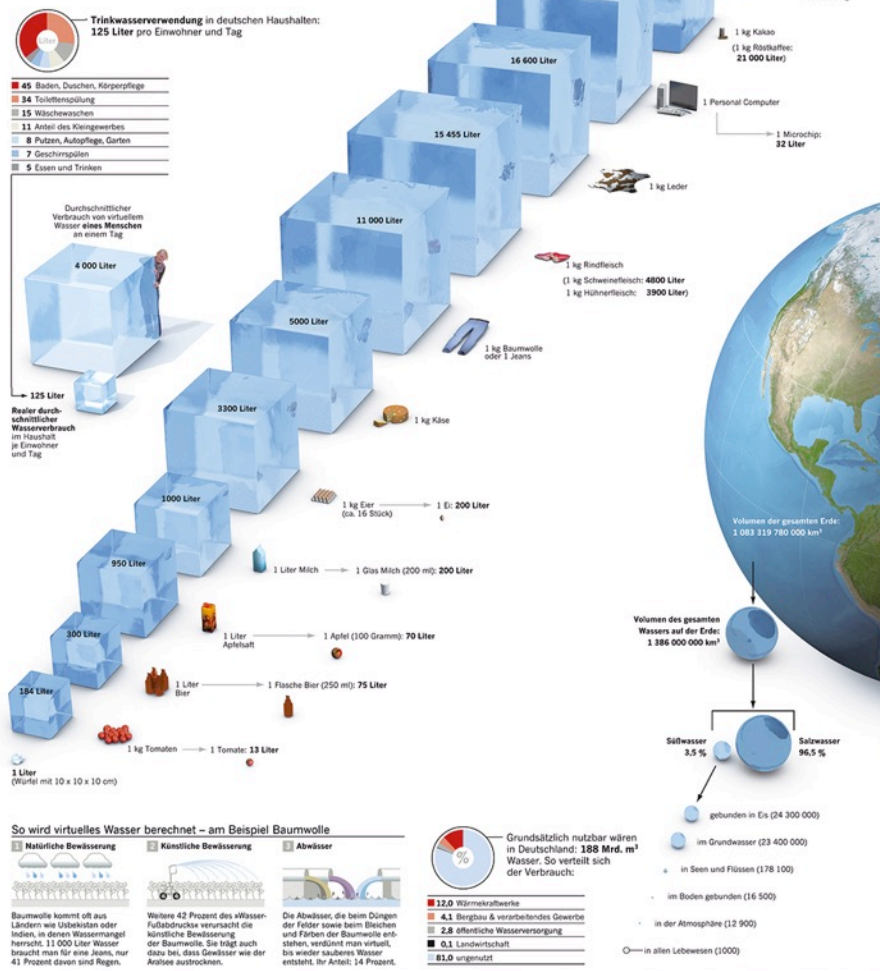


Figure 9. "How much water do we consume?"

For | Die Zeit newspaper by: Jan Schwachow (Golden Section Graphics).

This Infographic provides a unique visualization of our water consumption; comparing various objects' sizes to the amount of water we use, to emphasis the topic and increase comprehension. Comparison is one of the most important principles in creating effective infographics.



# Ordnung für Mekka

In der kommenden Woche beginnt die Wallfahrt nach Mekka. Sie ist der religiöse Höhepunkt im Leben eines Muslims – und ein Albtraum für jeden Logistiker. Massenpaniken mit Hunderten von Toten sorgen früher für Schlagzeilen. Nun hat Saudi-Arabien die Pilgerfahrt neu organisiert – mithilfe deutscher Ingenieure

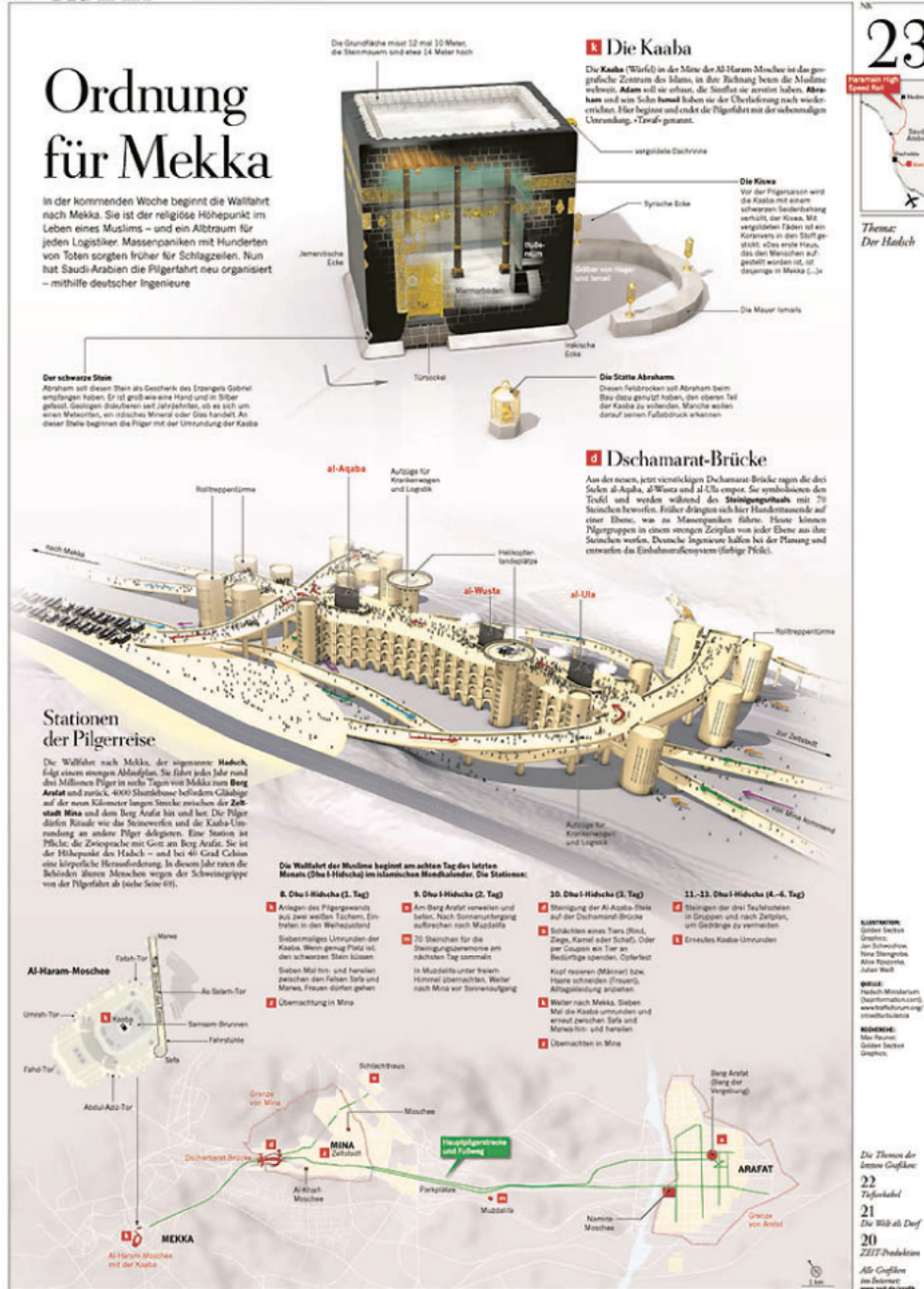


Figure 10. "Mecca & the Hadsch (Haddsch, hajj, haj, hadj)"

For | Die Zeit newspaper by: Jan Schwachow (Golden Section Graphics).

This Infographic describes the "Grand Kaaba" at Al-Masjid al-Haram in Mecca, Saudi Arabia the most sacred mosque by Muslims and the "Haj" an annual Islamic pilgrimage to Mecca. Also shows locations, events, and paths that Muslims should follow. Images serve to show scale (size of people compared to the new bridge) In addition, the map provides spatial information.

## Complejos cálculos permiten determinar que el número máximo de movimientos para resolver el cubo es 20

# Rubik encuentra 'el número de Dios'

Ernö Rubik, profesor de arquitectura húngaro, inventó el cubo en 1974

### LA FINALIDAD DEL JUEGO

1. Se mezclan los colores girando las capas del cubo



2. Se reordenan a su estado original, de modo que cada cara tenga sólo un color

### LOS GIROS DE LAS CAPAS

Las seis capas giran en los dos sentidos



Para resolver el cubo de Rubik, hay que conocerlo

Es un cubo de 6 caras, divididas en 9 partes cada una y compuesta por 26 piezas o cubitos



### HAY TRES TIPOS DE PIEZAS

12 piezas de borde de dos colores

8 piezas de esquina de tres colores

6 piezas centrales de un sólo color...

... que definen el de toda su cara. En la pieza central opuesta siempre corresponde el mismo color:

Esta es la combinación de colores más difícil, según los programas informáticos. El cubo está a tamaño real

Rojo Azul Amarillo  
Naranja Verde Blanco

Piezas centrales  
No se desplazan del centro porque forman parte de la estructura que articula el resto de las piezas

Articula todas sus piezas mediante un mecanismo interior

Mecanismo articulado  
Tiene un giro de 360 grados en los dos sentidos

1. Todas las piezas encajan como un puzle

2. En el interior del cubo, las piezas tienen un corte curvo...

3. ... para guiar la rotación de sus múltiples giros

La cara interna de las capas  
Los cubitos restantes quedan encajados en torno a las piezas centrales

La cara interna de las capas  
Los cubitos restantes quedan encajados en torno a las piezas centrales

La cara interna de las capas  
Los cubitos restantes quedan encajados en torno a las piezas centrales

La cara interna de las capas  
Los cubitos restantes quedan encajados en torno a las piezas centrales

La cara interna de las capas  
Los cubitos restantes quedan encajados en torno a las piezas centrales

La cara interna de las capas  
Los cubitos restantes quedan encajados en torno a las piezas centrales

La cara interna de las capas  
Los cubitos restantes quedan encajados en torno a las piezas centrales

La cara interna de las capas  
Los cubitos restantes quedan encajados en torno a las piezas centrales

La cara interna de las capas  
Los cubitos restantes quedan encajados en torno a las piezas centrales

La cara interna de las capas  
Los cubitos restantes quedan encajados en torno a las piezas centrales

La cara interna de las capas  
Los cubitos restantes quedan encajados en torno a las piezas centrales

La cara interna de las capas  
Los cubitos restantes quedan encajados en torno a las piezas centrales

La cara interna de las capas  
Los cubitos restantes quedan encajados en torno a las piezas centrales

La cara interna de las capas  
Los cubitos restantes quedan encajados en torno a las piezas centrales

La cara interna de las capas  
Los cubitos restantes quedan encajados en torno a las piezas centrales

La cara interna de las capas  
Los cubitos restantes quedan encajados en torno a las piezas centrales

La cara interna de las capas  
Los cubitos restantes quedan encajados en torno a las piezas centrales

La cara interna de las capas  
Los cubitos restantes quedan encajados en torno a las piezas centrales

La cara interna de las capas  
Los cubitos restantes quedan encajados en torno a las piezas centrales

La cara interna de las capas  
Los cubitos restantes quedan encajados en torno a las piezas centrales

### ALGUNAS VARIACIONES

Minicubo 2x2x2

La venganza de Rubik 4x4x4

El cubo del profesor 5x5x5

Megaminx 6 colores

La venganza de Rubik 36,46 seg

El cubo del profesor 1 min 07,25 seg

Megaminx 57,94 seg

La venganza de Rubik 36,46 seg

El cubo del profesor 1 min 07,25 seg

Megaminx 57,94 seg

La venganza de Rubik 36,46 seg

El cubo del profesor 1 min 07,25 seg

Megaminx 57,94 seg

La venganza de Rubik 36,46 seg

El cubo del profesor 1 min 07,25 seg

Megaminx 57,94 seg

La venganza de Rubik 36,46 seg

El cubo del profesor 1 min 07,25 seg

Megaminx 57,94 seg

La venganza de Rubik 36,46 seg

El cubo del profesor 1 min 07,25 seg

Megaminx 57,94 seg

La venganza de Rubik 36,46 seg

El cubo del profesor 1 min 07,25 seg

Megaminx 57,94 seg

La venganza de Rubik 36,46 seg

El cubo del profesor 1 min 07,25 seg

Megaminx 57,94 seg

La venganza de Rubik 36,46 seg

El cubo del profesor 1 min 07,25 seg

Megaminx 57,94 seg

La venganza de Rubik 36,46 seg

El cubo del profesor 1 min 07,25 seg

Megaminx 57,94 seg

La venganza de Rubik 36,46 seg

El cubo del profesor 1 min 07,25 seg

FUENTE: www.rubiks.com, www.youcandothecube.com y elaboración propia

Raúl Camañas / LA VANGUARDIA

FRANCESC BRACERO  
Barcelona

Si alguna vez se ha planteado intentar resolver un cubo de Rubik y nunca se había atrevido, anime: la solución está a sólo 20 movimientos como máximo y, en la mayoría de los casos, a menos. Esta es la conclusión a la que han llegado cuatro expertos que han unido sus conocimientos y un supercomputador de Google para conocer el llamado número de Dios, que algunos matemáticos han perseguido en los 30 años de existencia del famoso puzle tridimensional.

El grupo que ha determinado que el número de Dios es 20 (www.cube20.org) está formado por Morley Davidson, matemático

de la Universidad de Kent State; John Dethridge, ingeniero de Google; Herbert Kociemba, profesor de Matemáticas de Darmstadt (Alemania); y Tomas Rokicki, programador de Palo Alto (California). Y no era fácil. El cubo de Rubik, que hace tres décadas comenzó a venderse en todo el mundo, tiene más de 43 trillones de posiciones posibles. Para hacerse una idea, el número escrito es: 43.252.003.274.489.856.000. Lo peor de esa cifra mareante es que sólo hay una solución.

Para averiguar ese número máximo de movimientos, los investigadores dividieron todas las posibilidades en 2.200 millones de grupos que tenían 20.000 millones de posiciones distintas cada uno. Descartaron posiciones repetidas y simetrías, con lo que

redujeron las opciones a 56 millones de combinaciones. Ahí es donde entró en juego el supercomputador de Google para hallar el número que buscaban.

El cubo fue inventado en 1974 por el arquitecto y diseñador hún-

**El famoso puzle tiene 43 trillones de posiciones posibles y sólo una de ellas es la solución**

garo Ernő Rubik, que no se planteaba crear un pasatiempo, sino construir una maqueta para explicar geometría tridimensional. El cubo, compuesto por seis caras

coloreadas de 3x3 piezas, fue comercializado al principio en Hungría en 1977 como Cubo Mágico, pero cuando empezó a venderse en 1980 en todo el mundo, la empresa Ideal Toy Corporation le dio el nombre con el que se ha hecho famoso: Cubo de Rubik.

Desde entonces, se han vendido 350 millones de unidades en todo el mundo. Los hay comestibles, compuestos por oro y piedras preciosas, que contienen un reproductor de mp3 y con una infinidad más de usos, como el de llavero. También se han creado otros nuevos de más piezas, como 4x4x4 o 5x5x5, lo que complica mucho más su solución, y también con nuevas formas, como la de pirámide o esférica.

El récord mundial oficial en la resolución del cubo de Rubik lo

tiene el holandés Erik Akkersdijk, que lo resolvió durante el campeonato abierto checo del 2008 en sólo 7,08 segundos, aunque en internet se puede ver a Taylor Dawson resolver uno en su casa en 6,62 segundos, pero estos resultados caseros, al hacerse sin supervisión de un jurado y con condiciones controladas, no cuentan. En internet se puede ver también a una niña china de tres años que lo resuelve en 114 segundos, menos de 2 minutos.

Treinta años después de su lanzamiento, el cubo de Rubik es un icono del siglo XX. Tiene clubs de fans por todo el mundo y las guías para resolverlo están en la red al alcance de cualquiera. En un máximo de 20 movimientos y unos pocos segundos. A ver quién se atreve.

Figure 11. "Rubik's Cube"

For | La Vanguardia newspaper (2010) by: Raúl Camañas.

This Infographic explains how the Rubik's Cube Works. 3D Images serve as a self-explaining visualization. In addition, comparison is used to provide quantitative technical information and annotated illustrations provide step-by-step tutorials and solutions.



For | La Vanguardia newspaper /2012) by: Raúl Camañas.

This infographic visually explains the sinking of the Titanic in steps. Image dominance serves to show scale (showing storage size capabilities). In addition, annotated illustrations provide both causalities and spatial information of the wreck.



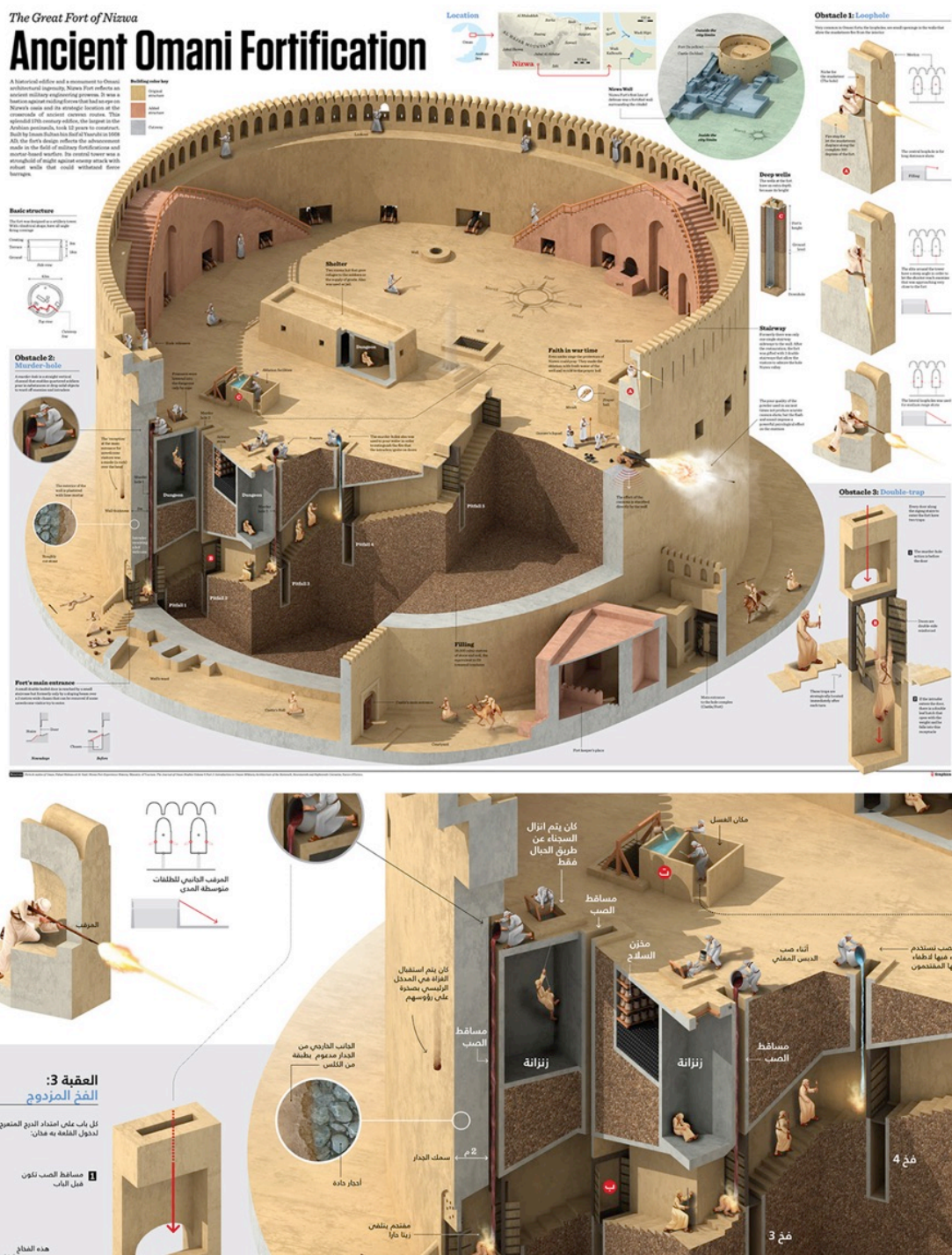


Figure 13. “The Great fort of Nizwa”

For the Times of Oman (English) and Al Shabiba (Arabic) newspapers, Muscat, Oman.  
by: Antonio Farach.

Again, the infographic applies the comparison principle through the use of image dominance to serve in showing scale and size of the fort. In addition, annotated detailed illustrations provide an interesting story-telling approach with extra technical and rich information.

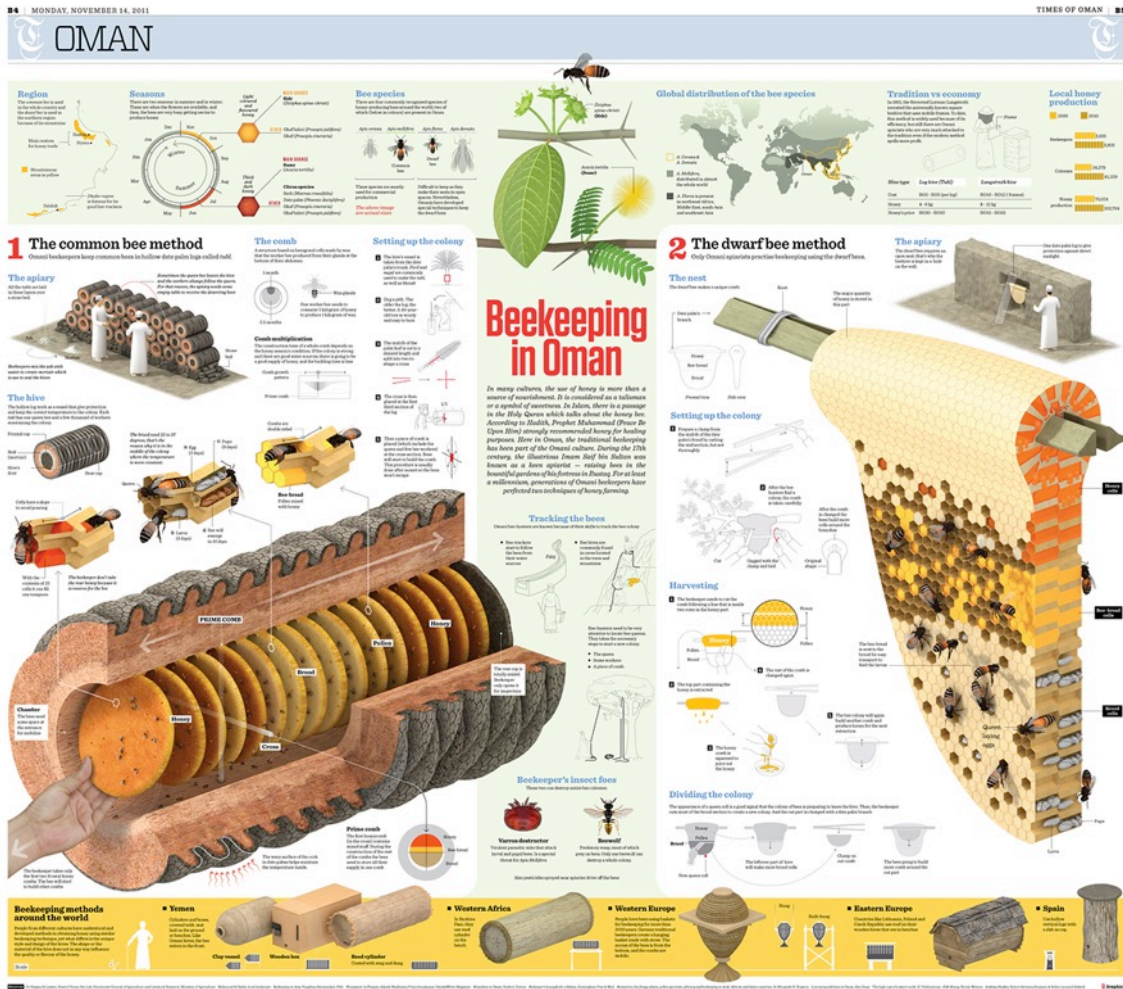


Figure 14. "Bee keeping in Oman"

Two pages spread info-graphic for the Times of Oman and Al Shabiba newspapers, Muscat, Oman. by: Antonio Farach.

This infographic visually explains two different unique methods of BeeKeeping in Oman. Comparison is used to show size and scale of the palm tree trunk method (notice the hand that catches the wax discs inside the trunk and the human figures compared to the trunks' size). In addition, annotated illustrations and some data visualization provide detailed technical and spatial information.



### The apiary

All the tables are laid in three layers over a stone bed.

Beekkeepers mix the ash with water to create mortar which is use to seal the hives

## The hive

The hollow log works as a vessel that give protection and keep the correct temperature to the colony. Each tub has one queen bee and a few thousand of workers maintaining the colony.

Diagram illustrating the components of a composite pipe: Frontal cap, Seal (mortar), Hive's core, and Rear cap.

Cells have a slope to avoid pouring

With the contents of 25 cells it can fill one teaspoon

The beekeeper don't take the rear honey because it is reserve for the bee

**Chamber**  
The bees need some space at the entrance for mobilize

The beekeeper takes only the first two frontal honeycombs. The bee will start to build other combs

The brood need 32 to 37 degrees, that's the reason why it is in the middle of the colony where the temperature is more constant.

The diagram illustrates the life cycle of a honeybee within a colony. It shows a cross-section of a beehive with several cells containing bees at different stages of development. The stages are labeled as follows:

- Queen:** A large, dark bee at the top left.
- a Egg (3 days):** A small, yellowish, oval-shaped egg.
- b Larva (5 days):** A white, worm-like larva.
- c Pupa (8 days):** A white, segmented pupa.
- d Bee will emerge in 16 days:** A new bee emerging from a cell.

The text at the top of the diagram states: "The reason why it is in the middle of the colony where the temperature is more constant." This indicates that the brood cells, where the young bees develop, are located in the center of the colony for optimal temperature control.

PRIME COMB



The wavy surface of the cork in date palms helps maintain the temperature inside.

## Setting up the colony

**1** The hive's vessel is taken from the date palm's trunk. *Fard* and *sagal* are commonly used to make the table as well as *khesab*

**2** Dug a pith. The older the log, the better. A 40-year-old tree is woody and easy to bore.

**3** The midrib of the palm leaf is cut to a desired length and split into two to shape a cross.

**4** The cross is then placed at the first third section of the log.


**5** Then a piece of comb is placed (which include the queen and few bee workers) at the cross section. Bees will start to build the comb. This procedure is usually done after sunset so the bees won't escape

### The comb

A structure based on hexagonal cells made by wax that the worker bee produced from their glands at the bottom of their abdomen.

A diagram showing two concentric circles representing an embryo. The inner circle is labeled '1 month' and the outer circle is labeled '2.5 months'.

One worker bee needs to consume 1 kilogram of honey to produce 1 kilogram of wax.



Wax glands

### Comb multiplication

The construction time of a whole comb depends on the honey season's condition. If the colony is strong and there are good water sources, there is going to be a good supply of honey, and the building time is less.

Diagram illustrating a comb growth pattern. A central vertical line is labeled "Prime comb". A horizontal double-headed arrow above it is labeled "Comb growth pattern". The diagram shows a series of vertical lines of varying heights, with the tallest line in the center, representing the prime comb, and shorter lines on either side, representing the growth pattern.

The rear cap is totally sealed. Beekeeper only opens it for inspection

### Prime comb

The first honeycomb (in the cross) contains mixed stuff. During the construction of the rest of the combs the bees need to store all their supply in one comb

For the Times of Oman and Al Shabiba newspapers, Muscat, Oman. By: Antonio Farach.

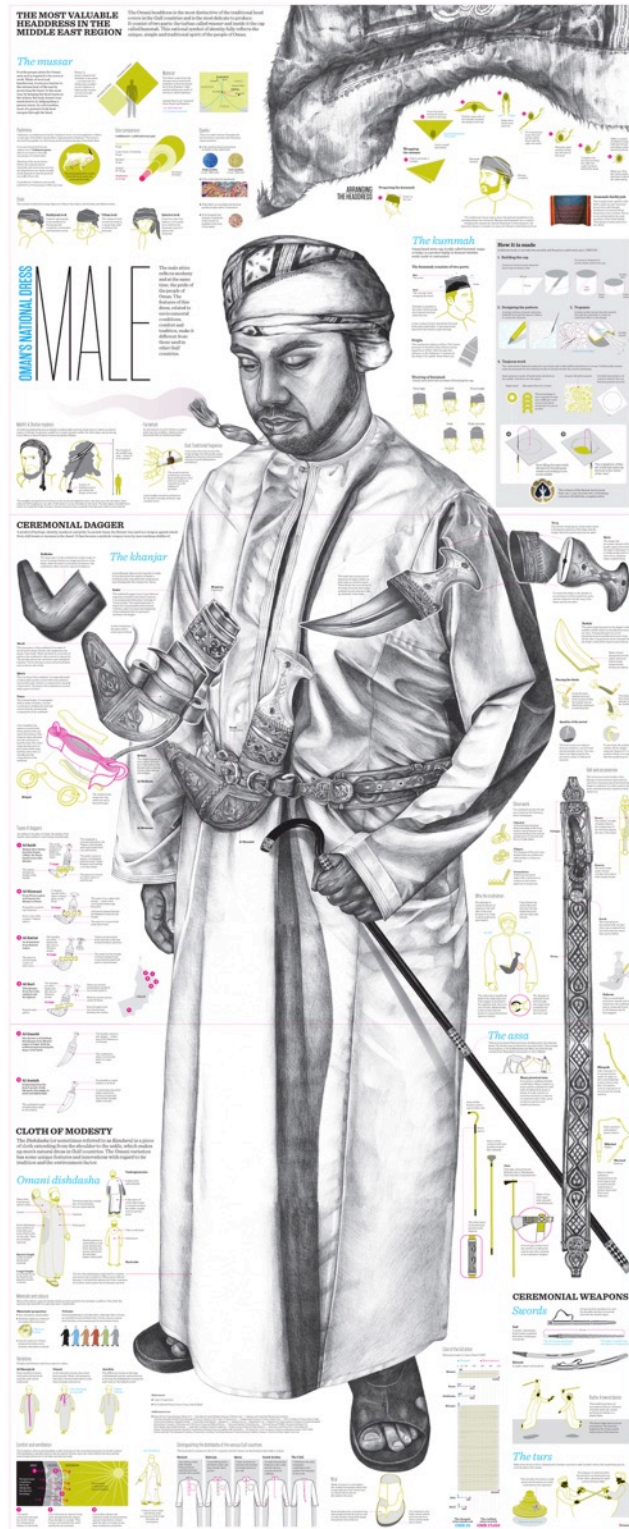


Figure 16. "Traditional Oman Dress (Male)" 2015.

A Giant 6 double pages spread info-graphic for Times of Oman newspaper. by: Marcelo Duhalde (Full infographic), Lucille Umali (Illustration), Antonio Farach (Editor), Adonis Durado (Art Direction), Isidore Vic Carloman (Illustration), Winie Ariany (Illustration).

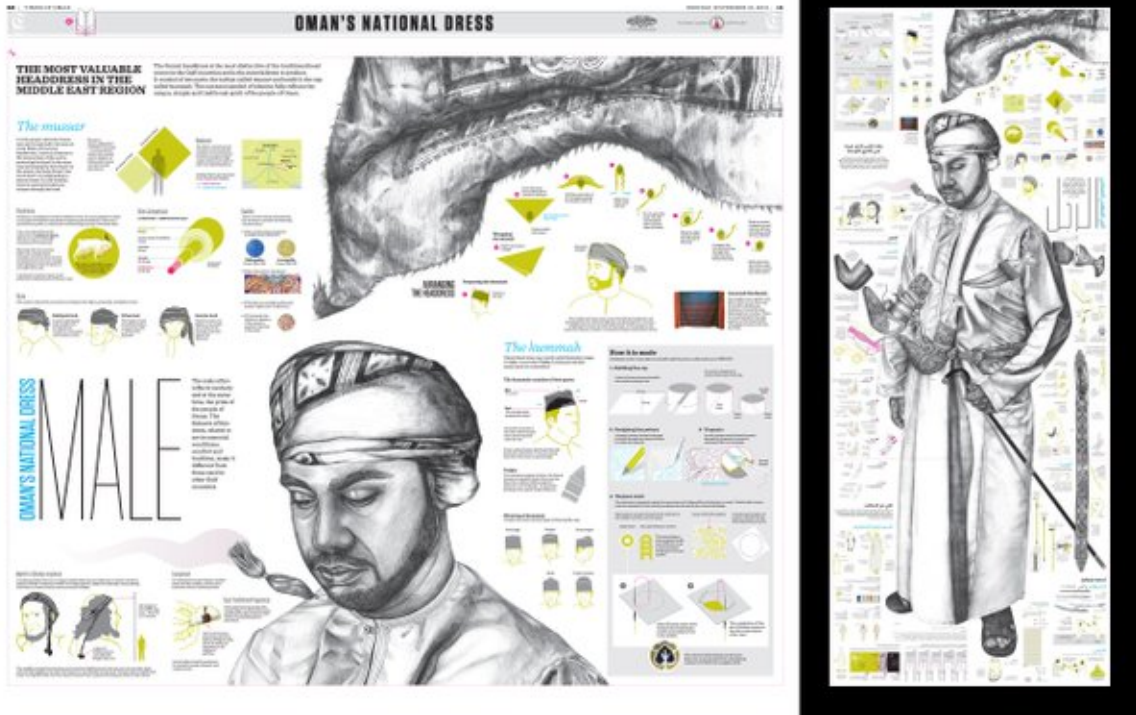


Figure 17. "Oman's National Dress (Male)" 2015.

First 2 pages spread from A Giant 6 double pages spread info-graphic for the Times of Oman and Al Shabiba newspapers, Muscat, Oman. by: Marcelo Duhalde (Full infographic), Lucille Umali (Illustration), Antonio Farach (Editor), Adonis Durado (Art Direction), Isidore Vic Carloman (Illustration), Winie Ariany (Illustration).

This giant infographic also utilizes comparison to visually describe the size of different scarves used to cover the head. Image dominance is not only aesthetically pleasing but also serves to show many details in the Omani traditional dress. In addition, surrounding annotated illustrations provide large amounts of detailed information and instructions for folding and wearing the headscarf.



Nowadays with the advancement in many online developing visualization tools and the 3D modeling & animation applications, these tools became more user-friendly and considerably easier to use than years ago. Publishers and visualization studios became more proficient to produce animated and interactive versions of their printed static infographics. The animated projects usually illustrate the same content available in the static format, in addition to the ability of viewing the process or data described in one continuous motion or animated scenes rather than separated steps or chunks of information. The relatively new animated or motion infographic formats attract more viewers and readers with their unique visual motion characteristics. Complex science subjects, events and process topics, that were relatively hard to explain and visualize in static print infographics, found the new motion medium capabilities as a great solution for creating an easy-to-comprehend experience for their audience. Examples of successful motion infographics can be found in the National Geographic Magazine Interactive version and on their online education website like “**How Hydraulic Fracturing Works**” (Fig 18) & (Fig 19).

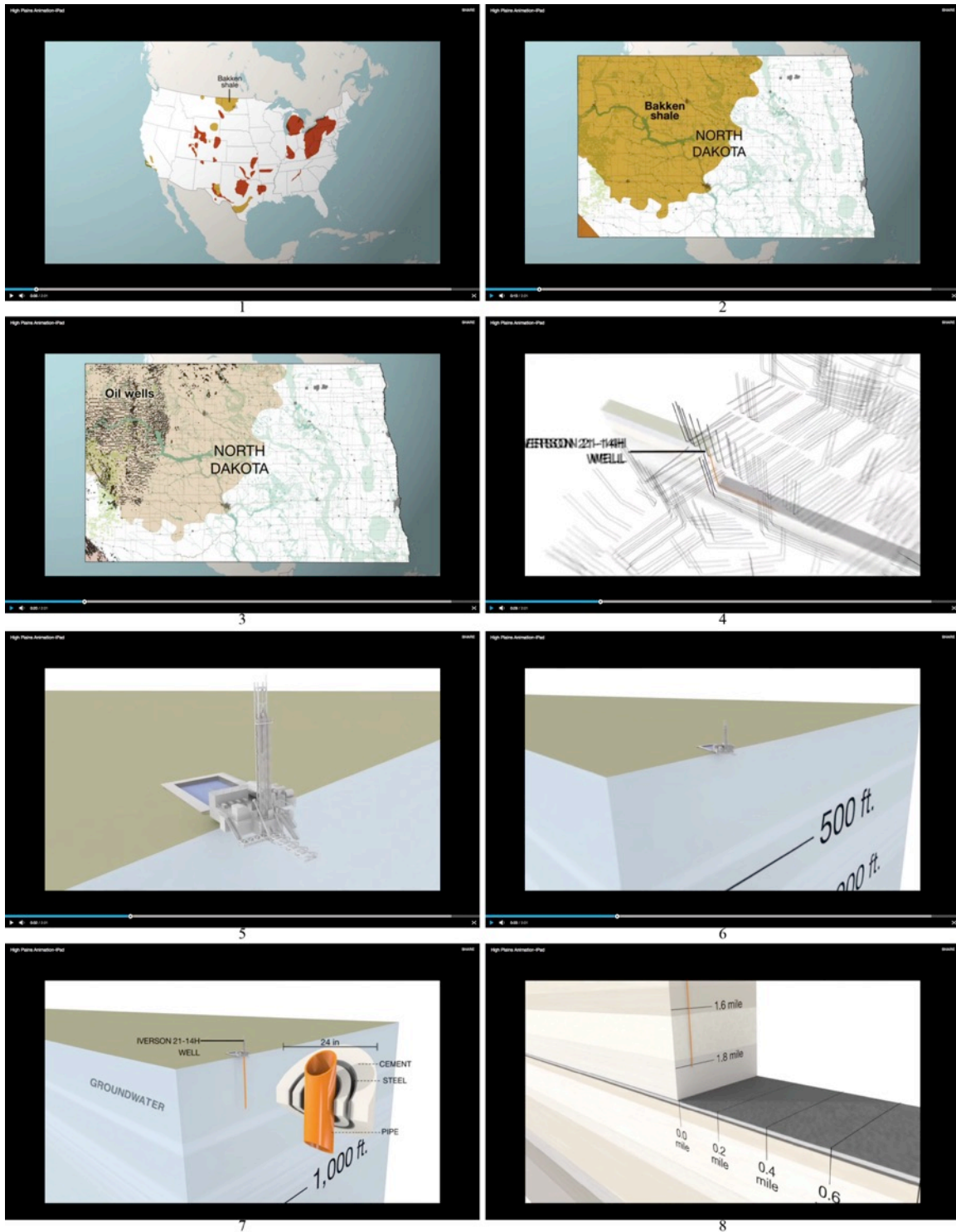


Figure 18. Captures from National Geographic Magazine Interactive version Motion Infographic “How Hydraulic Fracturing Works”  
<http://education.nationalgeographic.org>

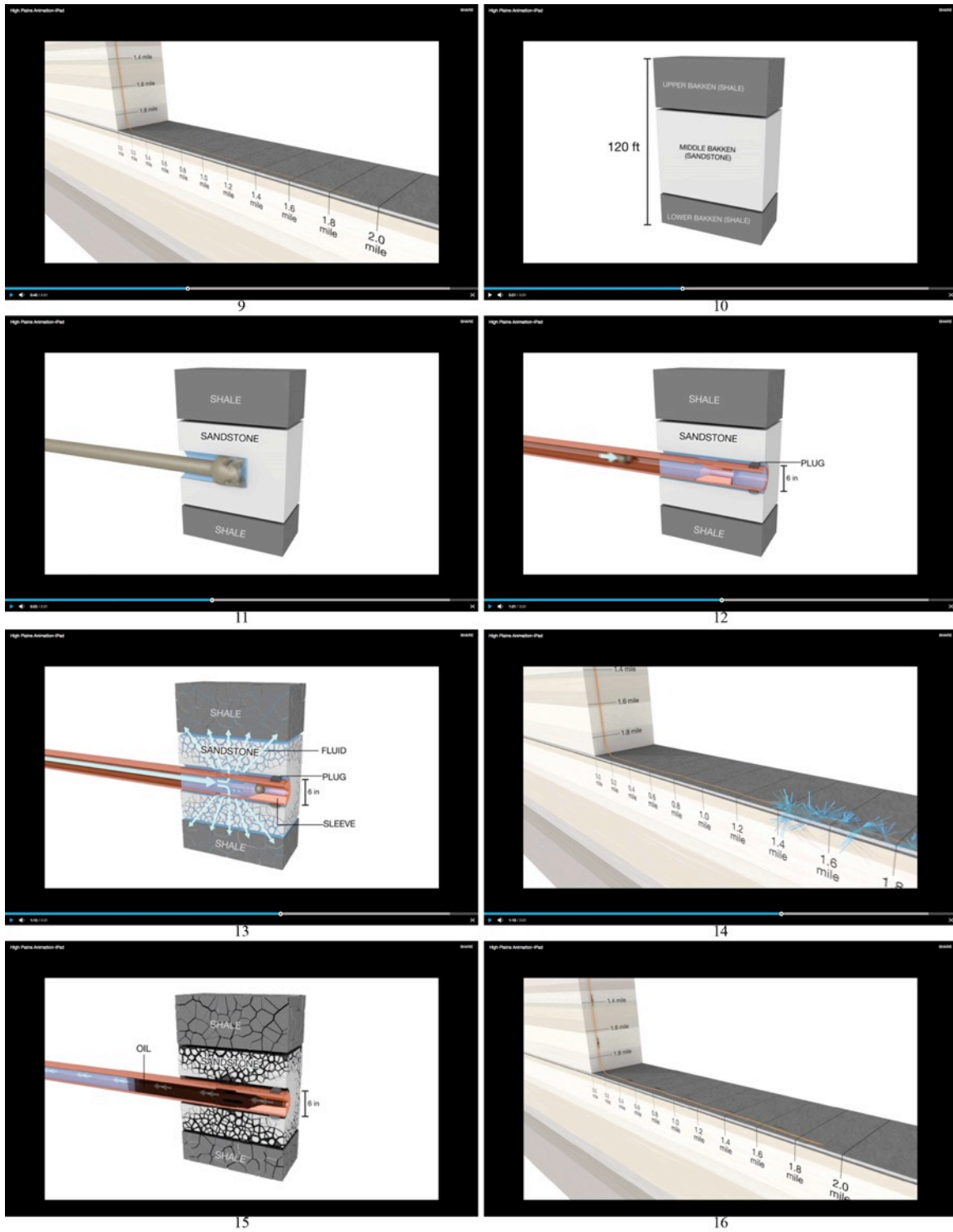


Figure 19. Captures from National Geographic Magazine Interactive version Motion Infographic “How Hydraulic Fracturing Works”  
<http://education.nationalgeographic.org>

## **2.5 Previous Studies On Narrated Animation And Static Infographics**

Mayer et al. (2005) reviewed previous similar researches on the learning efficacy of narrated animation versus static annotated graphics (Infographics), which were conducted by many studies. Some of them did not provide consistent proof to favor animated over static graphics (Narayan & Hegarty, 2002; Tversky et al., 2002; Hegarty et al., 2003). While other studies favored animation over static graphics; they stated that the animated versions included much more data and information than the printed static versions (Park & Gittelman, 1992). Also, in terms of complex systems, Tversky et al., (2002) stated that animation was not proven to do any better in providing an easier method for comprehension of the system.

### **Cases of static superiority**

To provide better testing conditions for analyzing the different media, Mayer et al. (2005) conducted a similar evaluation in which computer narrated animations were tested against printed annotated diagrams or illustrations. They used four different tests to evaluate the learning outcomes, distinguishing their study by providing similar content (data and information) in both the static paper based tests and the annotated animations. Though they tried to provide exact words in both versions, Mayer stated that it was impossible to design informational equivalent static annotated diagrams and narrated animation mediums because of other characteristics specific to the medium that cannot be provided in both, like stress and intonation in the narration. On the other hand, the static graphic provides limited frames or steps from the animation, whereas the animation provided one continuous motion of a subject.

The testing concluded that static media delivered a better learning experience in all four tests with different content when comparing retention and transfer measures, only when the Static and Animated mediums were equivalent in their information.

Moreover, they stated that this study does not mean that narrated animation graphics were ineffective on all other subjects or situations, but there may be specific settings or scenarios where animation facilitates comprehension and understanding.

In addition, Peters, D. (2013) stated that when learning complex cognitive tasks and scientific processes, animation provides the learners with more than what they need. Animation prevents the learner's mind from deciphering relations he can easily find between static images where he can view and read on his own pace. Consequently learning conceptual processes would be more effective using static formats.



## **2.6 What Is STEM?**

The acronym STEM has been a debated topic issue recently, discussed across educational organizations, journals and institutions. Federal policymakers at the United States have been discussing and showing interest in the STEM education too. STEM, which refers to Science, Technology, Engineering and Math, is not a name for an organization or institute. However, It refers to (STEM Education) which address the teaching and learning of the same fields: Science, Technology, Engineering and Math, at all levels of education ranging from pre-school to the graduate level. This involves all activities and strategies in teaching the subjects at all levels, inside the classroom and in after-school initiatives or programs.

Although statistics show that there has been an increase by 35% in the numbers of Science and Engineering graduate students during the last decade, the US is perceived as falling behind in regard to STEM education. Other related areas that have concerns about the future of STEM education is the quality of STEM teachers and the competency of American students, in comparison to the international STEM education levels and the ability of the American educational system to meet the increasing demand of STEM graduates for the future.

### **STEM and visual arts (STEAM)**

In reviewing the STEM field education while simultaneously investigating the importance of using visual aids (information graphics) to help and improve implementing STEM strategies, the question of the quality of education and improvement of both recognition and retention of information is raised. Ironically, where does teaching visual

communications and art fields stand with regard to STEM. Why is teaching art and visual communication not recognized as a direct benefit to what STEM stands for? Sure, It would be a great help in the long term, when visual and storytelling experts create teaching and visual aid frameworks that facilitate teaching complex science subjects and improving recognition and retention of information.

There is no doubt in the importance of teaching more art and visual communication for students. Nevertheless, proving how teaching arts may integrate with STEM educational strategies is not an easy or obvious task. A good example appears at the University of Pittsburg Medical Center (UPMC), where the Technology Development Center's researchers and employees who are responsible for creating health-care IT products include Visual Communication and Design professionals besides Clinicians, Engineers and Software Experts. Dr Rasu Shrestha from UPMC has been supporting the implementation of a more visual and artistic approach at the center.

“Art is such an important aspect to visual design, human computer interaction and design. How do you represent specific information so that it's as intuitive as possible?” (Rasu Shrestha 2012).

Moreover, The Rhode Island School of Design has been an advocate for moving from STEM to STEAM which means adding Arts to the acronym. Babette Allina, director of government relations at the school states,

“STEAM is different. Clearly, we want more art in the classroom, but, instead of focusing on STEM, think how art and science have a natural affinity and why is it being bifurcated. STEAM is a way to think about natural innovation by combining our strength in art and science.” (Allina, B 2012).

## **2.7 Basic Education & Learning Principles**

In order to achieve the highest degree of comprehension and maximize the learning experience in the classroom, educators and teachers follow a set of principles. Those principles contribute in organizing, clarifying and informing educational and pedagogical policy makers in creating effective educational strategy and tools. Moreover, learning aid material creators and designers benefit from applying the principles in the creation process of their materials, thus leading to the production of effective teaching aid frameworks that contribute in advancing the learning process.

Curtis Murphy mentioned six different main principles or laws of learning in his paper: “Why games work and the science of learning”. Murphy, C. (2011). The first three principles readiness, exercise and effect were developed by the renowned psychologist Edward Thorndike at the beginning of the twentieth century, the other principles: primacy, intensity, and recency were added at a later stage. In addition, Educational psychologists added two more principles, Freedom and Requirement. However, this thesis will focus on the main six principles as they are more related to the research topic.

### **1- Readiness:**

Readiness deals with the notion that the more students are ready to start the learning experience or the subject, the more gain they will be able to achieve and comprehend. The instructor could motivate the students to get ready for learning by showing interest in the subject or explaining the long-term benefits of learning. Additionally, readiness helps create progress and increases comprehension in their education when students have a clear, precise vision of what they need to learn and the importance of the subject.

**2- Exercise:**

Repetition is a key element in learning; meaningful exercises are crucial for learning and retaining information. The human brain lacks the ability to retain or gain a complete recognition in a single exposure. This requires teachers to keep reviewing main topics of a subject at regular intervals, which allows students to learn from practice and repetition. Every time students are exposed to the subject the learning process continues, and the important material become easier to comprehend and recall.

**2- Effect:**

The feelings and emotions every experience or lesson leaves on the student after learning it play a great part on the learning and educating of the lesson. Difficult subjects leave students with frustration and discomfort about their abilities to success and learn. Thus, teachers should create an environment where each student could feel and be able to demonstrate some success, even if the subject is too complex or difficult to understand. Emotional experiences are easier for the brain to understand and recall with clarity and detail, and pleasant experiences are more likely to be successful and effective methods in learning and education.

**4- Primacy:**

When teaching a process or subject for the first time it should be taught in the most appropriate technique or method. Re-teaching a process or new technique, as a correction of a previously taught method, usually takes a longer time to adopt as students can seldom change their first learned false or bad habits.

**5- Recency:**

The more recent the subject is learned or reviewed, the easier it is recalled and remembered by students. Teachers usually create summaries of lessons they have already taught, in order to be reviewed at the end of each lecture. This helps increase the retention of main topic issues in the mind. Trying to remember the main points of yesterday's lesson is much easier than recalling last month's lesson.

**6- Intensity:**

The number of details and the closeness to real life situations that are present in a learning experience advances the learning and understanding of the subject. Intensity means: immersing the student with more details within the subject taught using visual and instructional aid materials, the more comprehensible and retained the topic will be. For example: teaching a science subject through videos and graphics that visually explain the topic, increases understanding and comprehension more than reading pure linear textual material about the same topic. As the class room is considered to be limiting, the interaction learning ability available in an outdoor environment, using teaching aid frameworks like interactive information graphics and videos in integration with the teachers presentation and instruction skills achieve the intensity required for the subject.

**2.8 Multiple Intelligences (MI)**

“Multiple Intelligence Theory” as a new study (or science) on learning and education, supports and advocates the ability of each human being to learn by using different types of intelligences, each with its individual strength or weakness. So, utilizing these

intelligences in combination together helps and advances the learning ability and process.

*“It is of the utmost importance that we recognize and nurture all of the varied human intelligence's, and all of the combinations of intelligence's. We are all so different largely because we all have different combinations of intelligence's. If we recognize this, I think we will have at least a better chance of dealing appropriately with the many problems we face in the world.”* **Howard Gardener, via** (Armstrong, T. 2009).

The theory was developed by one of the leaders in modern education theories, Professor Howard Gardener, professor of education at Harvard University. Simply, his theory states that the traditional thinking about measuring human intelligence according to the result of their I.Q. test is not enough, and there are more means to measure and assess intelligence than this limited result.

Gardener provided eight different intelligences that exemplify all the capabilities of the human mind and described each one as a possible unique talent or ability of different individuals. The following is a description of intelligences, and how they could affect the learning capabilities of their beholders.

### **1- Linguistic – Verbal (They are word smart)**

This intelligence is about the ability of making good use of words and language; they are good at speaking and writing. People who possess this intelligence have the ability to manipulate words and create rhetoric language to affect other's behavior. They learn more effectively by reading, writing and listening.

### **2- Logical-Mathematical (They are logic smart)**

This intelligence belongs to those who prefer to use logical thinking and numbers to

comprehend and exemplify other things. Accountants, computer programmers and mathematicians fall under this category. They learn by analyzing patterns, classifying and categorizing, and by determining cause and effect.

### **3- Visual-Spatial (They are image smart)**

People who possess this intelligence have a great ability to use their mind's visual recognition to process accurate information and to perform different tasks according to their visual comprehension like artists, illustrators, interior decorators, graphic designers and architects. They have a sensitive eye to notice color, shape, form, and space. Thus, they can perform artistic tasks easily and efficiently. Students possessing a spatial intelligence learn best by visualizing all teaching aids, like pictures, diagrams, movies, slides, illustrated books and surely infographics.

### **4- Bodily-Kinesthetic (They are body smart)**

This intelligence is simply the natural endowment of athletes, actors, dancers, surgeons, mechanics and craftspersons. They have the ability to use their bodies or hands to produce or transform things or express feelings. In addition, they have high physical abilities and skills, like flexibility, strength and dexterity. Students with a high haptic or kinesthetic intelligence learn by hands-on training, touch and movement, as their ability to acquire information through their body is considerably high.

### **5- Musical (They are music–auditory smart)**

This intelligence describes the ability of those people who love music and can easily learn and play musical instruments, compose or critic music melodies and tones, and are music-auditory smart. They have higher skills in terms of hearing tones and rhythm. Students with this intelligence are good listeners and learn through singing and listening to tones and music.

### **6- Interpersonal (They are people smart)**

A person with the capability to deal and interact competently with others simply describes this intelligence. It is about how to motivate people and to react according to their interpersonal cues. Thus, one can affect their motivations and actions. People with high interpersonal intelligence can be successful sales persons, managers, teachers and leaders. Students who possess this intelligence learn by sharing and cooperating with others through group games, community events, and they benefit a lot from their mentors.

### **7- Intrapersonal (They are self smart)**

This intelligence describes the ability of people who comprehend their capabilities, limitations, and abilities to react according to this understanding for their success. A capacity to control their own emotions enables self-control and self-esteem. Students with intrapersonal intelligence prefer to learn on their own, where they can achieve maximum efficiency. They are much more capable to be better organized with themselves than to work with groups, setting their own goals and working to achieve them.

### **8- Naturalist (They are nature and earth smart)**

Being knowledgeable and aware about your own environment is what naturalistic intelligence is about. Gardener added Naturalistic to the intelligences in 1999. Other associated skills are the ability to understand and distinguish between multiple species (various plants and animals and how they relate to the well-being of the ecosystem and earth). In addition, the awareness of natural phenomena formations (land and terrain, clouds and storms) is considered to be part of this Intelligence. A similar intelligence exists in those who are nurtured in urban areas rather than more nature-related environments like the countryside, as they may possess the ability to distinguish and



categorize non-living objects (ex: cars, brands and different architecture styles). The crucial need of this capacity flourished during the agrarian period and still has a need to maintain a balanced healthy ecological system through the efforts of environmental experts and activists. Students with such ability learn best through field trips, interacting with the environment, animals and utilizing nature exploring tools.

Studying and identifying those capabilities or intelligences (MI) in each individual would greatly help to determine other methodologies needed to develop teaching strategies based on each person's or student's strengths and weaknesses. In other words, if a student is well-developed in visual-spatial and music intelligences, but faces problems with linguistic abilities, like slow reading, he would be guided through more tailored activities that enhances linguistic skills. Thus, tailored, designed, visual teaching aid solutions should be created with emphasis on targeting weak intelligence areas.

## **2.9 Information Graphics and Retention**

Lankow in *"Infographics: The Power of Visual Story Telling"* identified three primary provisions that should exist in any visual communication methods, they are:

- “1. Appeal: Communication should engage a voluntary audience.
2. Comprehension: Communication should effectively provide knowledge that enables a clear understanding of the information.
3. Retention: Communication should impart memorable knowledge.” (Lankow, Ritchie and Crooks 2012)

This means that any visual display should have one or more of those three elements in order to properly perform its intended mission or convey a message. A good visual

design should be appealing in order to attract the target audience and entice them to get deeper into the display. What makes a design more comprehensible? By utilizing the needed and scientifically proven information design methods and rules that facilitate understanding. Finally, what makes a design or visualization more memorable? By targeting the visual receptors of the human brain that process data and create memories. Though, those three topics simultaneously formulate the core essence of excellence in graphic communication, “Retention” as a main issue related to education and what constitutes a proven success in terms of teaching and learning is the ability to retain and recall the information by the human brain will be explored deeper later in this thesis.

### **1- Aesthetically pleasing - Appeal:**

“The aim of the poet is to inform or delight, or to combine together, in what he says, both pleasure and applicability to life.” Horace, *Epistolas Ad Pisones De Ars Poetica*

As we are living in the information age and “Big Data” terminologies and explanations, various information inputs and mediums stimulate our senses and pervade nearly every aspect of our daily tasks and lives. Thus, a well-illustrated and carefully designed display is crucial to delight and attract the audience to your design, moving them from just “Having a look at” to the “Getting deeper into” status, and maintaining their exploration of the display for longer periods, consequently getting the most from its content. A good design is what differentiates one product from another, making it stand out and sell successfully, even if it is composed of the same features as similar products. When it comes to pure data design or visualization, there is no difference to deal with it in the same way a product is designed to target high sales figures.

“People need an added incentive to eat their vegetables—especially when those vegetables are as cold and dry as research studies and analytics reports.”

(Lankow, Ritchie and Crooks 2012)

A study at the University of Saskatchewan proved that participants favored a more illustrated style of data design over plain ones. There is more than one way to create aesthetically pleasing visual displays of data. This could be achieved through a variety of methods, included but not limited to, using illustrations, visual metaphors, attractive colors and shades, decorative elements and symbols or icons. Nevertheless, proper integration of those illustrative elements, according to the subject and application of the display, is crucial to the success of the design. Otherwise, over-used graphics may distract the audience from the intended communicated information.

## **2- Cognition and comprehension of visual displays:**

Researchers identified that humans learn and comprehend information through three types of stimuli: Visual, Auditory and Kinesthetic or Tactile. This was based on Neil Flemings’s VAK Model. The model simply identifies different types of learners:

1-Visual learners: Their ability to learn and acquire information reaches its maximum efficiency, through pictures and other visual graphics like graphs and illustrations.

2-Auditory learners: They favor listening to spoken words in order to achieve proper comprehension.

3-Kinesthetic learners: Comprehension through touch and physical activities. The VAK model suggested that the three models of learning have equal states on how people may benefit from their different senses when it comes to acquiring and comprehension of

information. Nevertheless, nowadays people are surrounded by visual stimulus all over the globe, more often than the other remaining two, this occurs through the huge amount of data experienced through multiple channels like the Internet and other visual media resources. Moreover, Ware in *Information Visualization: Perception for Design* states,

“We are able to acquire more information through our visual system than we do through all other senses combined” (Ware 2012).

Thus, the primary learning and comprehension method would be visual. So, what is the main factor that facilitates comprehension and recognition visually? Ware described what methods and solutions the human brain utilizes to comprehend information through visuals quickly and efficiently without the need to excel extra efforts and time.

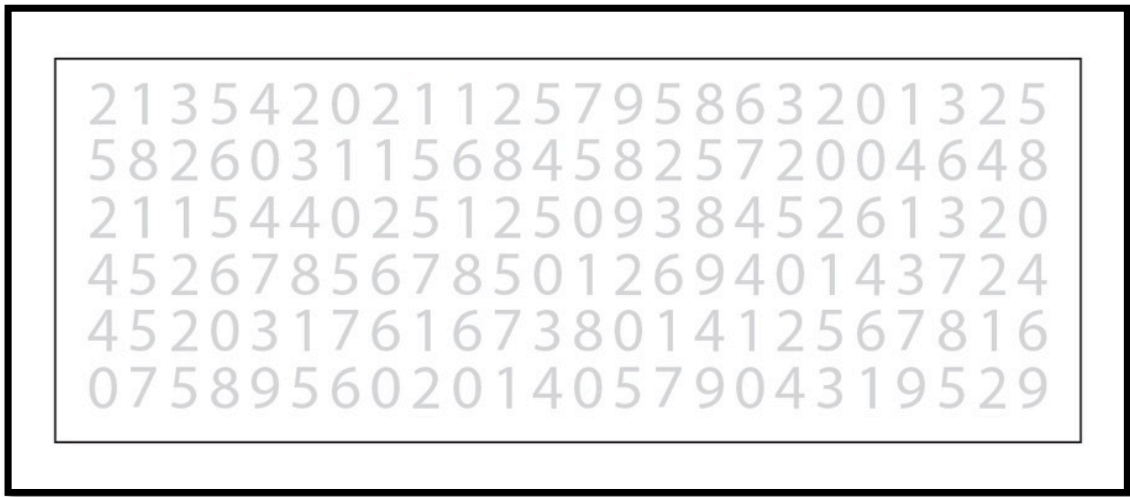
“The human visual system is a pattern seeker of enormous power and subtlety.

The eye and the visual cortex of the brain form a massive parallel processor that provides the highest-bandwidth channel into human cognitive centers. At higher levels of processing, perception and cognition are closely interrelated, which is why the words understanding and seeing are synonymous (Ware 2012).”

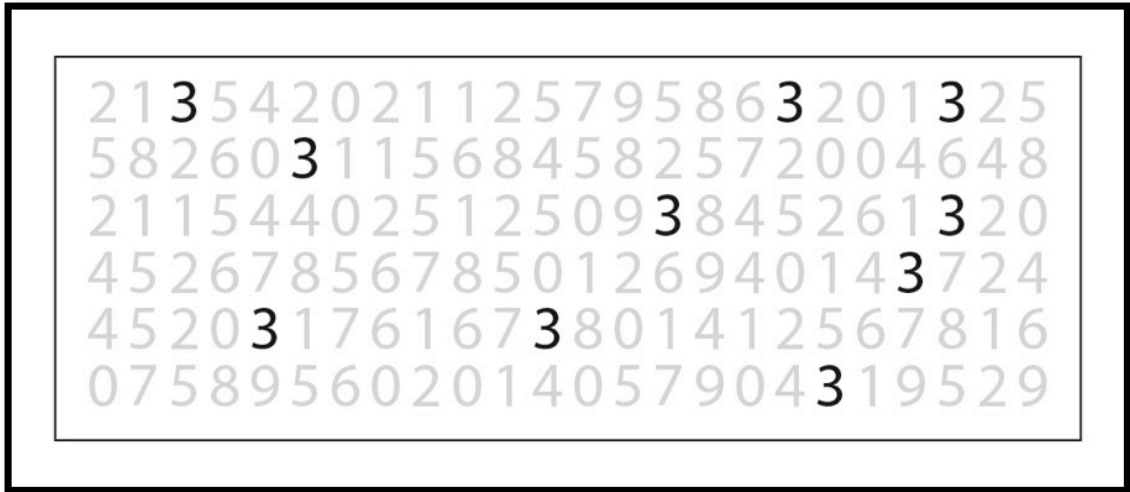
The methods used by the brain and the visual system when acquiring information is called pre-attentive features or attributes. The visual brain is a pattern seeker and uses those attributes effortlessly to make sense of various visual elements, detect differences and group similar shapes and objects together in order to save the data processing time and finally perceive bigger objects as a whole. The perception process happens in a fraction of a second, started by a quick-eye visualization of an attribute and sending the images for processing by the brain unconsciously, without any recognized or extra mental efforts. In contrast, the attentive perception is when the visual system excels conscience

effort and time trying to make proper perception of the visual elements. The first unconscious perception happens, as mentioned, extremely fast without extra effort and can even recognize several attributes simultaneously. While the later takes more time and effort to perceive data and takes place in a sequential manner.

Figure 20 & 21 exemplifies the most common pre-attentive attribute (Color & Shade), the figure is a modified version of a picture created by Stephen Few.



*Figure 20. The most common pre-attentive attribute (Color & Shade)*  
The figure is a modified version of a picture created by Stephen Few.



*Figure 21. The most common pre-attentive attribute (Color & Shade)*

The figure is a modified version of a picture created by Stephen Few.

Trying to count how many number “3’s” are in Fig. 20, would require some time and effort from the brain and would take a sequential conscious process to accomplish. On the other hand, the number of “3’s” in Fig 21 would be easily and pre-attentively recognized without any conscious effort from the brain. This is due to the different pre-attentive attributes that were applied to the number “3’s” and that the remainders of the numbers lack in Fig. 21. Other pre-attentive attributes include: size, orientation and shape. A full list of pre-attentive attributes appears in Fig. 22 created by Stephen Few.

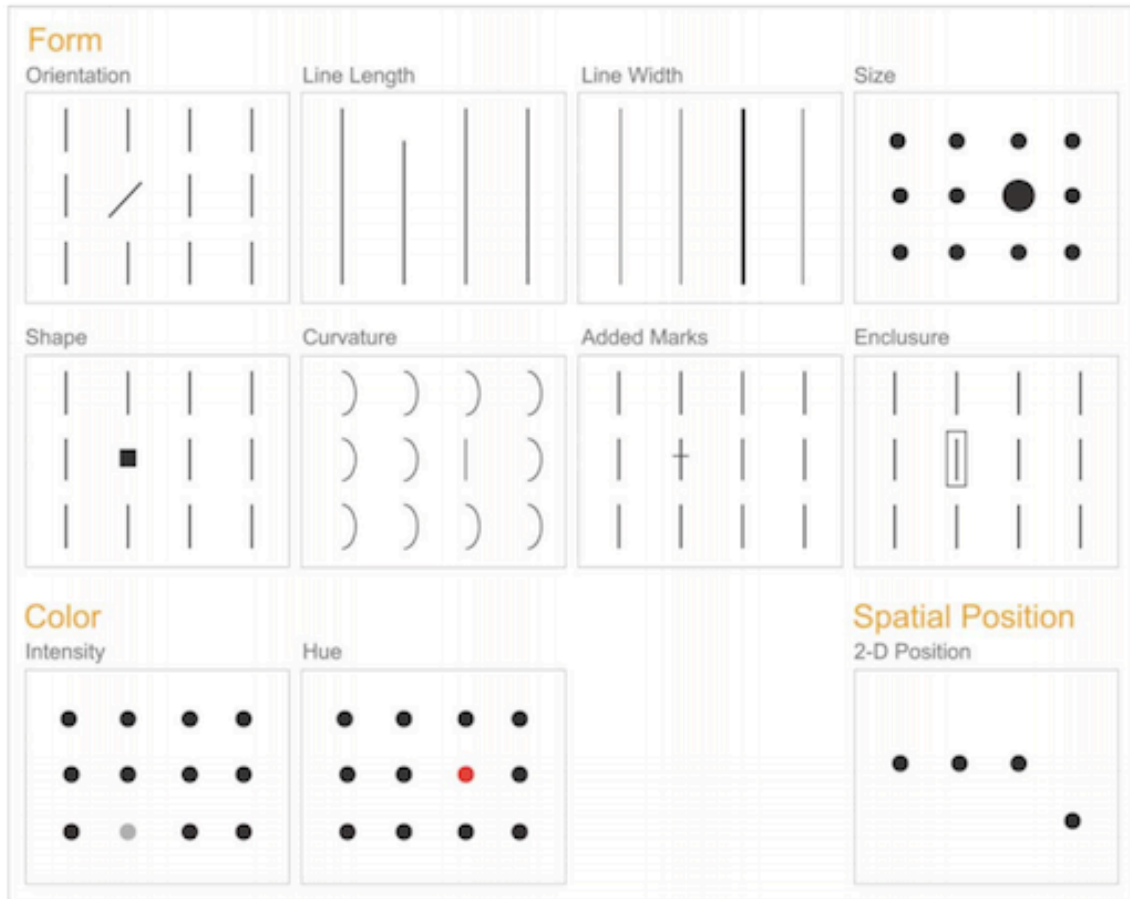


Figure 22. (*Tapping the Power of Visual Perception*, 2004, Stephen Few)

Information designers can excel in creating excellent visual displays and information designs that can be perceived effectively and effortlessly by the human mind, and consequently facilitates the learning process. This could be easily achieved by utilizing the pre-attentive features within the design. However, those visual attributes varies in term of perception as some of them could be used successfully to visualize quantities by using numeric values while others may be much more efficient in visualizing spatial trends.

### **3- Retention**

Human beings strive to constantly learn and make sense of their surroundings by analyzing their environment through everyday observations. The methods and tools our brain uses to acquire and store that new information varies in many different ways. In order to improve our ability to learn and retain the acquired data, we must understand what tools and methods best help the human brain store information for long periods of time in order to be ready for recall when needed.

**How quickly the brain forget things depends on many factors which includes:**

- 1- The difficulty of the subject (rocket science or medical issues).
- 2- How meaningful the subject is to the learner. (Some people love Math where others do not. Others enjoy playing a musical instrument, which means reading about their beloved instrument and how to use it or the various methods of manufacturing a violin, for instance, would be an easy interesting subject to comprehend for them, more than other learners who are not interested in music at all).
- 3- How the subject is introduced and learned (Through plain text, video presentation or illustrated information)
- 4- How frequently the subject is reviewed after the first learning.
- 5- Other psychological factors including stress, anxiety and sleep.

**How infographics help in increasing retention:**

In regard to the factor number three in the previous paragraph (How quickly the brain forgets things depends on many factors which includes) deals with how the subject learned was introduced, psychologically proves that using the proper method and format



for delivering the subject in the learning environment. Here the method could be data designed in an infographic style, which utilizes more visual elements and graphics than pure text books, and the format determines how the infographics are delivered: a static infographic (printed materials, posters, or digital static displays published online); digital motion graphics, video or interaction information design (online or delivered as games on DVD) helps to greatly prevent forgetting the subject and consequently improving retention.

### **Memory, forgetting and education or learning**

In contrary to the concept that forgetting is considered to be a malfunction of the human brain, which affects our ability to constantly learn and recall our hard longtime earned education. Actually, the human brain keeps getting rid of useless events or memories to improve other useful and much more important memories. So, forgetting information is not necessarily a useless brain function, this evokes the queries: what causes the retention of other needed data, particularly for the learning purposes?

### **Information retention & learning**

Information retention is a crucial aspect and key element in any successful teaching process. Teachers and educators thrive constantly to achieve a higher information retention percentage in their classrooms through various learning and teaching methods and skills. In order to explore what improves and increases retention of information we must first identify how information is stored in the human brain or what is called memory, waiting for an easy and quick retrieval method. Colin Ware mentioned the

importance of visualization when recalling data from the long-term memory, as visual displays work as connection between what the eye views, and what is already stored as a non-visual data in the long-term memory.

Richard Atkinson and Richard Shiffrin developed a model describing the human memory and published in a 1968 paper titled “Human memory: a proposed system and its control processes. Stanford University”. The model is considered to be the most popular model when studying and researching the human memory. It simply describes that human memory has three separate components, and that information is stored in the human brain through those different kinds of memory or components:

- 1- Sensory Memory (Iconic)
- 2- Short Term Memory (Visual Working Memory)
- 3- Long Term Memory

**Sensory or Iconic Memory:** The name comes as we acquire this memory first through our senses and then through viewing objects using the human eye. This is the very first scene the human visual system retains for a very short time (A fraction of second), it is like an extremely quick picture of what the eye views, waiting for extra processing by the help of the brain and other memories.

**Visual Working Memory:** is also a very short-term memory with a limited capacity in processing visual information; an average of only five items can be handled in the visual working memory. However, it works as a bridge between Iconic and Long-Term Memory. When an iconic memory subject needs extra explanation, visual working memory is what connects the visual information gained through the iconic memory to the long-term memory, trying to get the needed extra non-visual information from the long-

term memory, in order to comprehend the subject. Roberto Cairo mentioned the most recognizable written paper about visual working memory “The magical number seven, plus or minus two: some limits on our capacity for processing information” written by Princeton University Psychologist George A. Miller in 1956. Cairo elaborated to say that recent academic papers claim that the number of items that can be handled through visual working memory is even smaller like four or less. (Cairo 2013).

“The limited capacity of our visual working memory helps explain why it's not advisable to use more than four to five colors or pictograms to identify different phenomena on maps and charts. Most readers are not likely to remember what they represent” (Cairo 2013).

**Long-Term Memory:** is the permanent memory that stores information and experiences and the associated emotions. The brain, as mentioned, constantly provides the visual working memory with information from the long-term memory, in an attempt to recognize the objects or data processed in the visual working memory.

### **Infographics improve cognition and retention**

This process, between the stored knowledge in the long-term memory and the acquired pictures through the visual system and iconic memory, provides recognition and understanding in a magnificent effective way comparing to other non-visual sensory acquired information.

Thus, visual display **Infographics** improve cognition and retention of information by providing the brain with easy methods and tools (visual elements and pictures) that are designed particularly to meet the brain's ability to quickly decipher various kinds of data

& images and consequently build on long-term memory and recall information quickly.

“Useful junk?: the effects of visual embellishment on comprehension and memorability of charts” a study by Scott Bateman et al (2010, April), suggests that the more illustration-based the design is, the more its ability to retain and recall its communicated information by the viewers when tested for a long-term retention process. The study shows a significant ability from the participants to recall different types of information (Subject, Categories and Trends) when presented within a more visual illustrative-based design than when presented within a text only design. Bateman explains his findings from the study that: using more images and illustrations in the design facilitates the process of building deeper memories by providing extra iconic pictures to associate information with, and consequently benefits long term memory.

Many other psychology research studies support the notion that pictures (or graphics) are valuable in building long-term memories and information recall. Gambrell & Jawitz, authors of the “Mental imagery, text illustrations, and children's story comprehension and recall” 1993 paper, claim that illustrations and images within instructional text improved fourth-grade children’s abilities in terms of comprehension and recall of narrative text.

Lastly, visual elements/illustration types could be used as effective tools in the Infographics creation process! Lankow (2012) provides three different devices to be considered when creating illustrative infographics: Visual Metaphor, Symbols and Iconography and decorative Framing.

**Visual Metaphor:** This is can be achieved by creating illustrations that indicate or represent the subject matter of the infographics, like using a panther image or illustration to represent something that is very fast and speedy like a sports car.

**Symbols and Iconography:** This is usually used in infographics to replace extra verbal explanations and minimize the use of text, symbols and icons like a “Twitter bird” which represents the Twitter online service or a heart shape which represents love can be used effectively to convey meaning and provide extra information. However, cultural issues should be taken into consideration, to make sure that the icons are well recognized and understood by the infographic’s target audience.

**Decorative Framing:** The use of illustrative or iconic elements to add visual interest to the data and information in the infographic, this helps to engage the audience with the data communicated on a personal level and consequently increase information retention. A simple example of using decorative framing appears in the use of an icon or an illustration of a soda bottle or a cup filled with a drink next to copy text or title that talks about beverages or drinks.

## CHAPTER 3. METHODOLOGY AND PROCEDURES

### 3.1 Introduction

This thesis involves the creation and design of an animated infographic that visualizes and explains a complex science subject (Phases Of The Moon). The animated format was chosen for testing against a static format, because I hypothesized that an animated dynamic infographic accompanied with narration should help learning spatial and temporal science subjects more effectively than a static infographic containing only annotated illustrations and diagrams. Sound and movement will be more effective in communicating the complexity of the subject, especially when we can see and hear at the same time. In addition, the same data and information content of the animated infographic will be used to create a static format in order to compare the efficacy of both formats in terms of comprehension and information retention.

What differentiates and advances this infographic testing over previous research on similar learning outcomes, such as testing the efficacy of learning from annotated illustrations and narrated animation, is the subject complexity. A complex science subject which involves both spatial and temporal data (Phases Of The Moon) has been chosen, which could support teaching in the STEM field. This will be the main subject content of the infographic rather than simply testing how complex systems work, which was tested previously (Mayer. et al, 2005.)

#### **Previous static moon phases visualization case studies (*static format deficiency*)**

Several existing visualizations were studied to determine their success and shortcomings (Figs. 23-26). A major approach in most of the previous static visualizations of the Moon

Phases was that each moon phase stage was portrayed in two different perspectives simultaneously and juxtaposed next to each other. One showed how the moon looks from the space view and the other showed how the moon looks when viewed from the earth. It is possible that the double perspective may confuse learners in terms of comprehending the illustrations or diagrams and in differentiating between the two perspectives as shown in Figures (Fig 23) and (Fig 24).

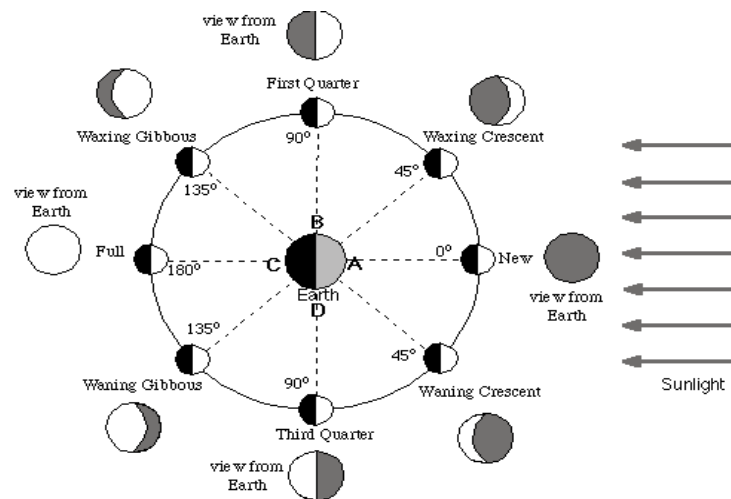


Figure 23. The Moon Phases by [www.moonphases.info](http://www.moonphases.info)  
Retrieved January 6, 2016, from [http://www.moonphases.info/moon\\_phases.html](http://www.moonphases.info/moon_phases.html)

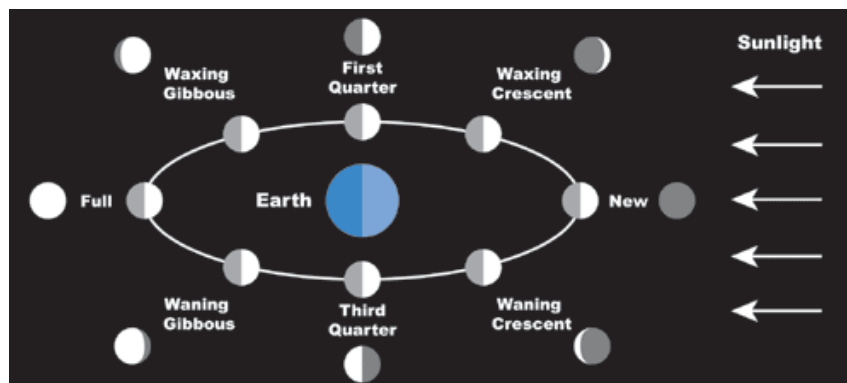


Figure 24. Phases of The Moon by [www.spaceplace.nasa.gov](http://www.spaceplace.nasa.gov),  
Retrieved January 6, 2016, from <http://spaceplace.nasa.gov/review/dr-marc-earth/moon-phases.html>

**Previous animated moon phases visualization case studies**

Many previous animated visualization or motion graphic attempts for explaining the Moon Phases have their own visual deficiencies. Studies tried to solve the two different viewing angles (the earth perspective and the space perspective) problem (which I believe is the crucial and most important part in creating a good solution for visualizing the causes of the different phases) by providing a separate, smaller, second frame to show the changes in the Moon phases from the Earth's perspective within the main video frame, which shows how the moon orbits around the earth. This solution deficiency is breaking the line of sight of the learners and appears in the motion educational infographics created by Kids Educational Games and Phil Hart (Figs 25 & 26). In my opinion this actually repeats the same approach of the juxtaposed static illustrations of the moon phases, which have the same deficiency (breaking the line of sight) and the animation here adds little to help in comprehending the subject. Any future animated infographics for the same subject should solve the problem of breaking the line of sight and provide the learners with a visual solution to this deficiency. A solution should provide learners with the experience and feeling of being able to view each moon phase while navigating a 3D space for the subject.



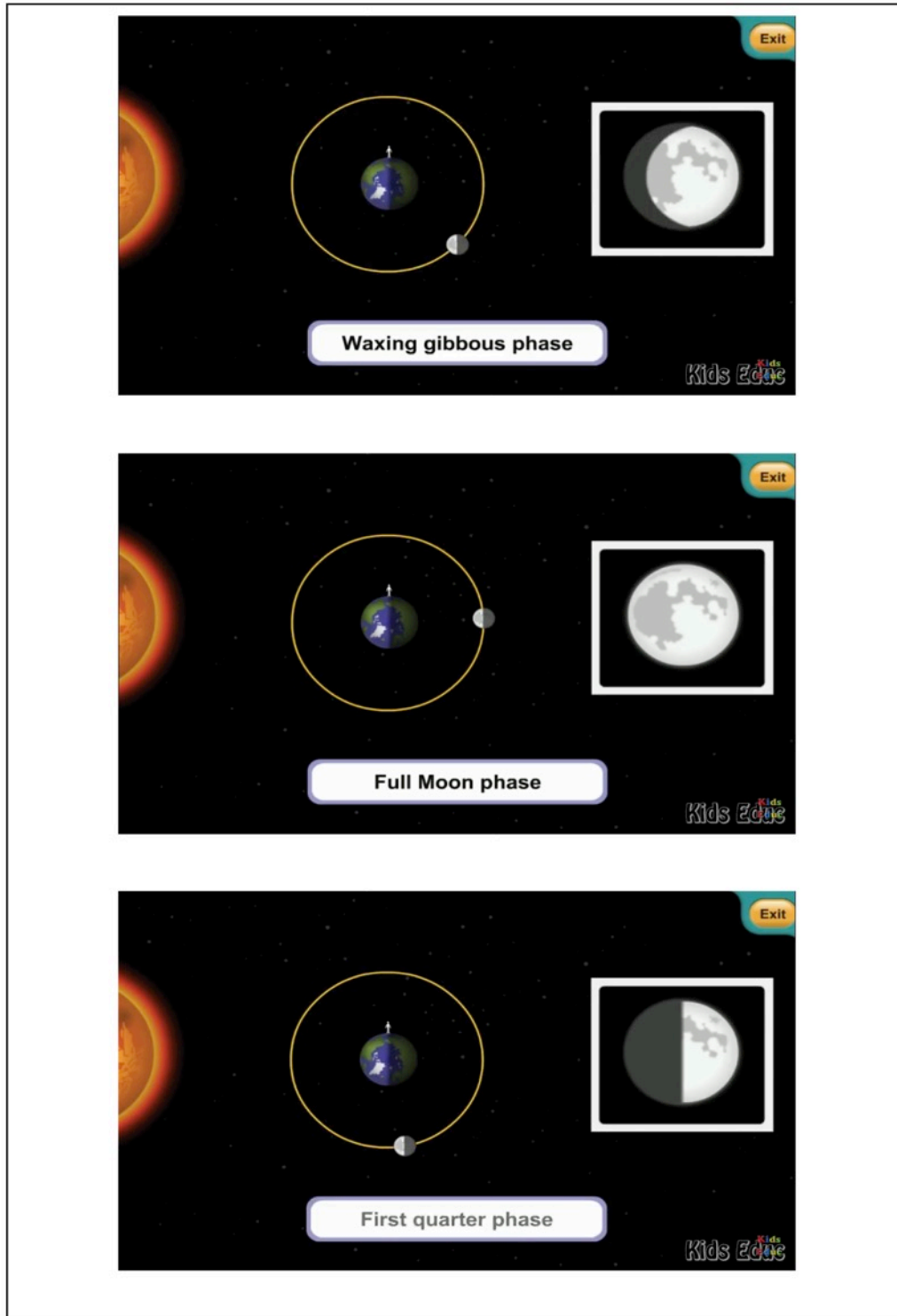
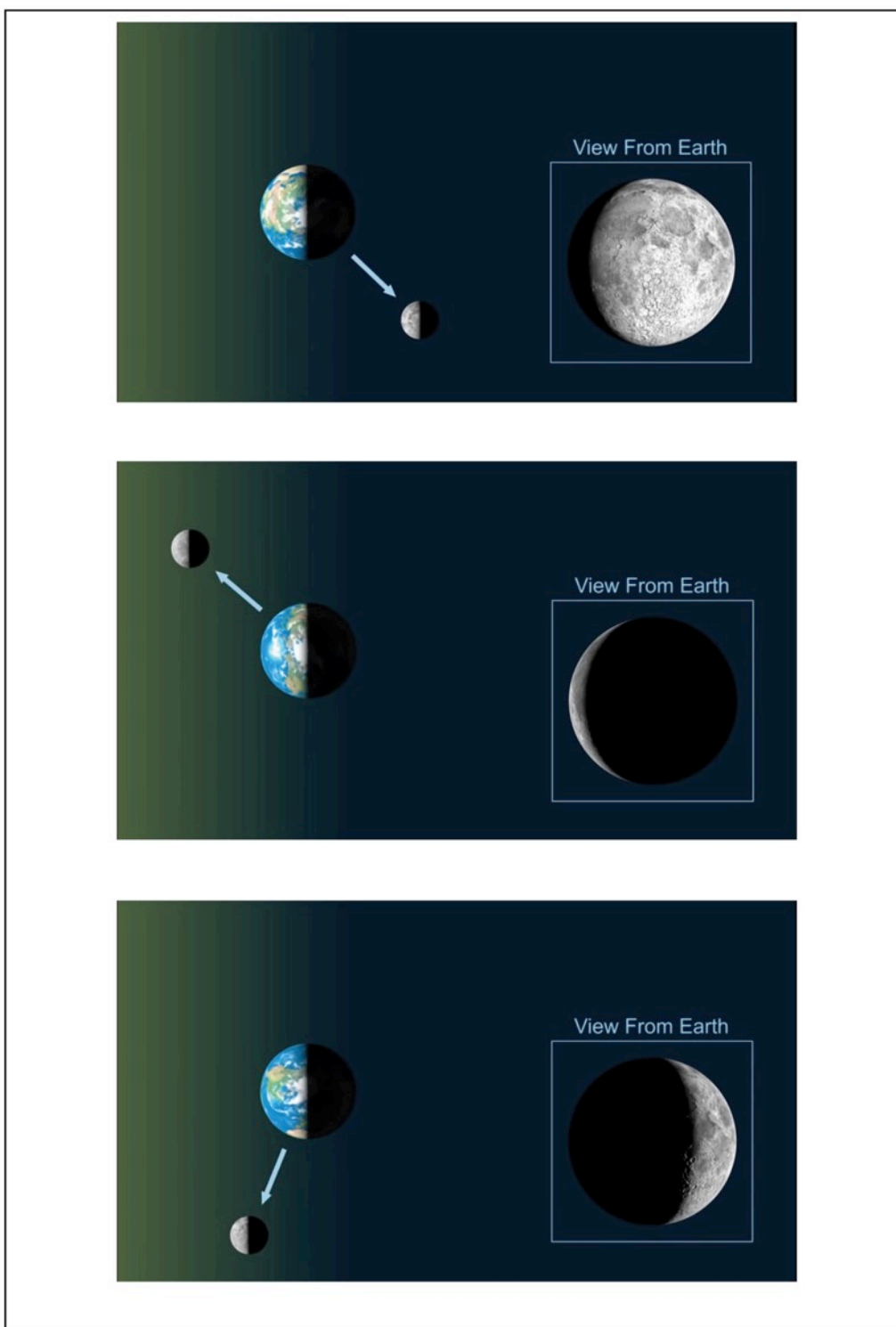


Figure 25. Captures from "Lunar Cycle, Why The Moon Change Shapes, 8 Phases Of The Moon, Learning Videos For Children. (n.d.)."

Retrieved January 5, 2016, from <https://www.youtube.com/watch?v=NCweccNOaqo>  
By KidsEduc – Kids Educational Games.



*Figure 26. Captures from "Animation of Phases of the Moon"*  
 By Neil Creek for the photography e-book Shooting Stars by Phil Hart:  
<http://philhart.com/shooting-stars> Retrieved January 5, 2016, from  
[https://www.youtube.com/watch?v=LHD4Pk0D8\\_g](https://www.youtube.com/watch?v=LHD4Pk0D8_g)

## **3.2 Moon Phases Visualization Design Process**

### **3.2.1 Infographics design principles usage**

As mentioned in the literature review and in order to follow the information design principles stated by Tufte (2006) I tried to use the principles as the subject allowed. The Multivariate analysis principle has been utilized in both the animated and the static formats, as follows:

- 1- Direction: In the moon's movements as orbiting the earth.
- 2- Location: The moon location with respect to the earth and sun according to each phase.
- 3- Size: As appears in the visible part of the moon at each phase.
- 4- Speed or time: The moon takes to show each phase and to complete one orbit around the earth.

### **First experience with the moon phases topic**

My very first experience with the topic of Moon Phases started when I was working as an infographics designer and editor with a daily Arabic newspaper (Alyaum, Saudi Arabia) and was asked to design a full-page infographic about the eclipse of the moon, as a real moon eclipse was taking place on the same day. I designed the page and explained the moon's phases to clarify the differences between them. Later I decided to create a different version in English that explained the causes of the moon's phases to be published online (Fig 27). Although these versions used the same two-perspective solution, which was mentioned before as inspired by previous attempts for moon phase visualizations, the English version received welcoming and affirmative comments online and received a "staff-picked" tag from the renowned infographics and design online company Visual.ly.

# 8 Phases Of The Moon,

.....Each Lunar Month

## What causes the moon phases?

The moon appears in various phases, starts by the New Moon Phase, transforms into the Waxing Crescent, appears as a Full Moon and ends in a Waning Crescent.

One half of the moon surface is always illuminated by the Sun rays as it faces the Sun while the other half is always dark. However, people on Earth see the illuminated half from different viewing geometries depending upon the moon's angle to that specific part of the earth during its rotation, which causes the Moon phases.

## How Total Lunar Eclipse Occurs



## Difference between Lunar eclipse and moon phases

It takes the moon a full lunar month to show its various phases during its rotation around the Earth. On the other hand, during the phenomenon of lunar eclipse, one can observe all the shapes the moon takes during the various phases in a short span of time. Within a period of only 4

hours the moon can be viewed in a partial eclipse, total Eclipse as well as during the ending phase. (A partial lunar eclipse occurs when only a portion of the Moon enters the umbra. When the Moon travels completely into the Earth's umbra, one can observe a total lunar eclipse).

## Real timing Steps of a Lunar Eclipse ..

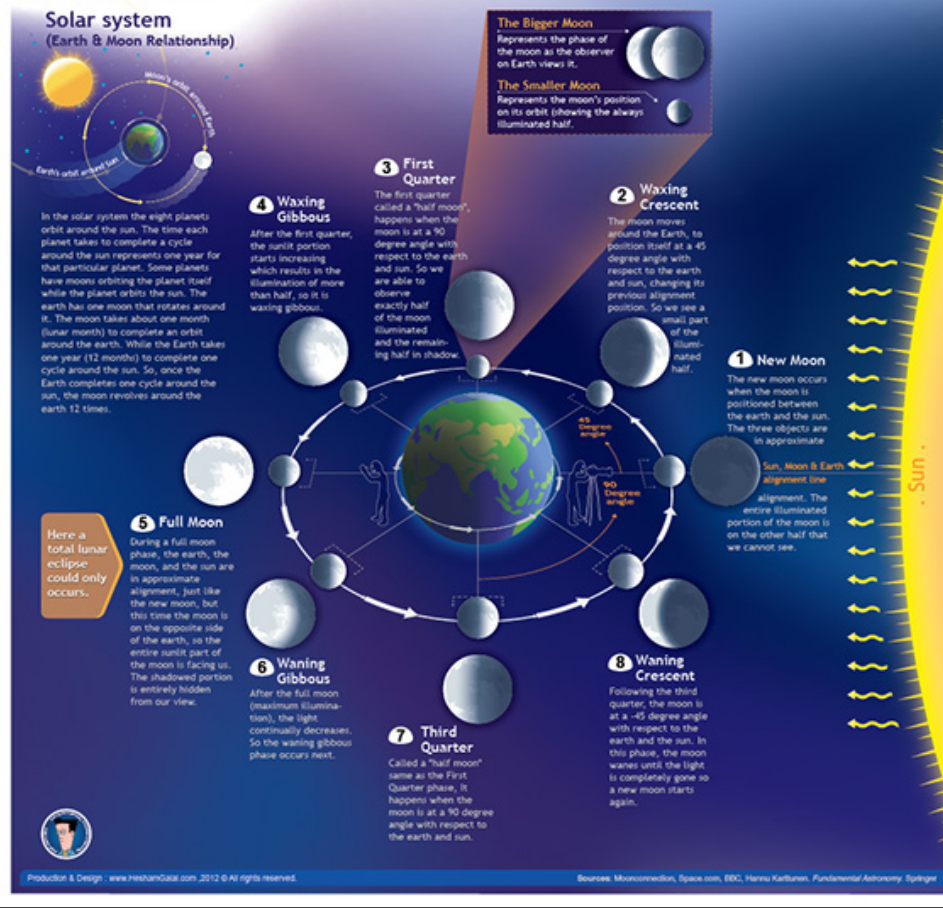


Figure 27. Eight Phases of the Moon Poster, designed by the author

### **3.2.2 The motion camera**

For a better visual solution that eliminates the visual deficiencies in previous examples (breaking the viewer's line of sight between the two angles), I tried to follow a much more effective way that increases brain recognition and does not break the line of sight, which is keeping the eye sight along the transition from one angle or point of view to the next, without any breaks. Using computer animation software, I created the camera movement that smoothly transfers the viewer's eye from the "space-viewing" angle perspective, where the view shows how the moon orbits the earth with only one half of the moon's surface illuminated, to the "viewer-on-Earth" viewing angle where each actual phase can be viewed.

This animation approach tries to solve the juxtaposed visualization problem mentioned above in the static format, which has existed in most of the current static visualization illustrations of the Moon Phases. Both the animated format and another similar static, printed format, which displays the exact same content of the animated format, will be tested with the hypothesis that the animated infographic format should provide a better comprehension experience for this specific subject. The text content of the static format will match the verbal-narration content of the animated format exactly. Nevertheless, the static format will still be hampered by the same previous juxtaposed visualization problem as mentioned above.

### **3.2.3 Creating the animated format process:**

#### **First trial**

My first trial in creating the animation was in a graduate-level animation class in the spring of 2015. I sketched my ideas in terms of several screens and scene shots

(storyboard), so that I could illustrate the overall animation, story and scenes that needed to be modeled and animated (Fig 28). At this stage I had no previous experience with the different animation tools and capabilities of the computer 3D software. I tried to show different points of view and angles of the moon but was not yet able to create the required camera movement, so the final result was not satisfying. (Fig 29) shows still shots from the first animation.

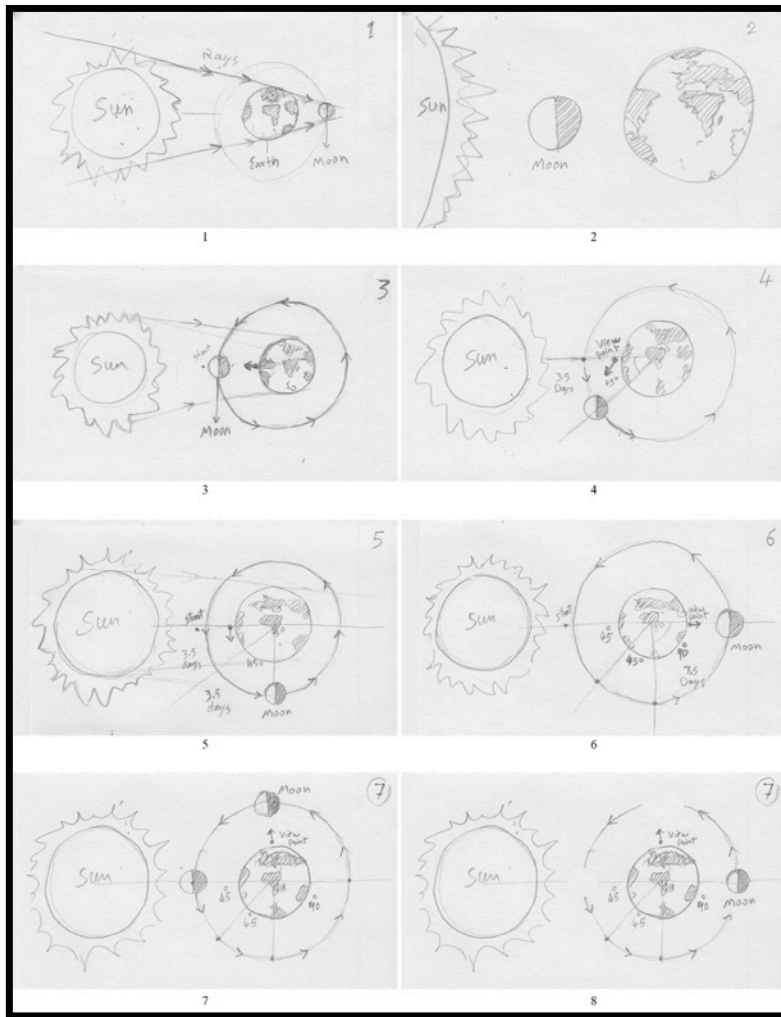
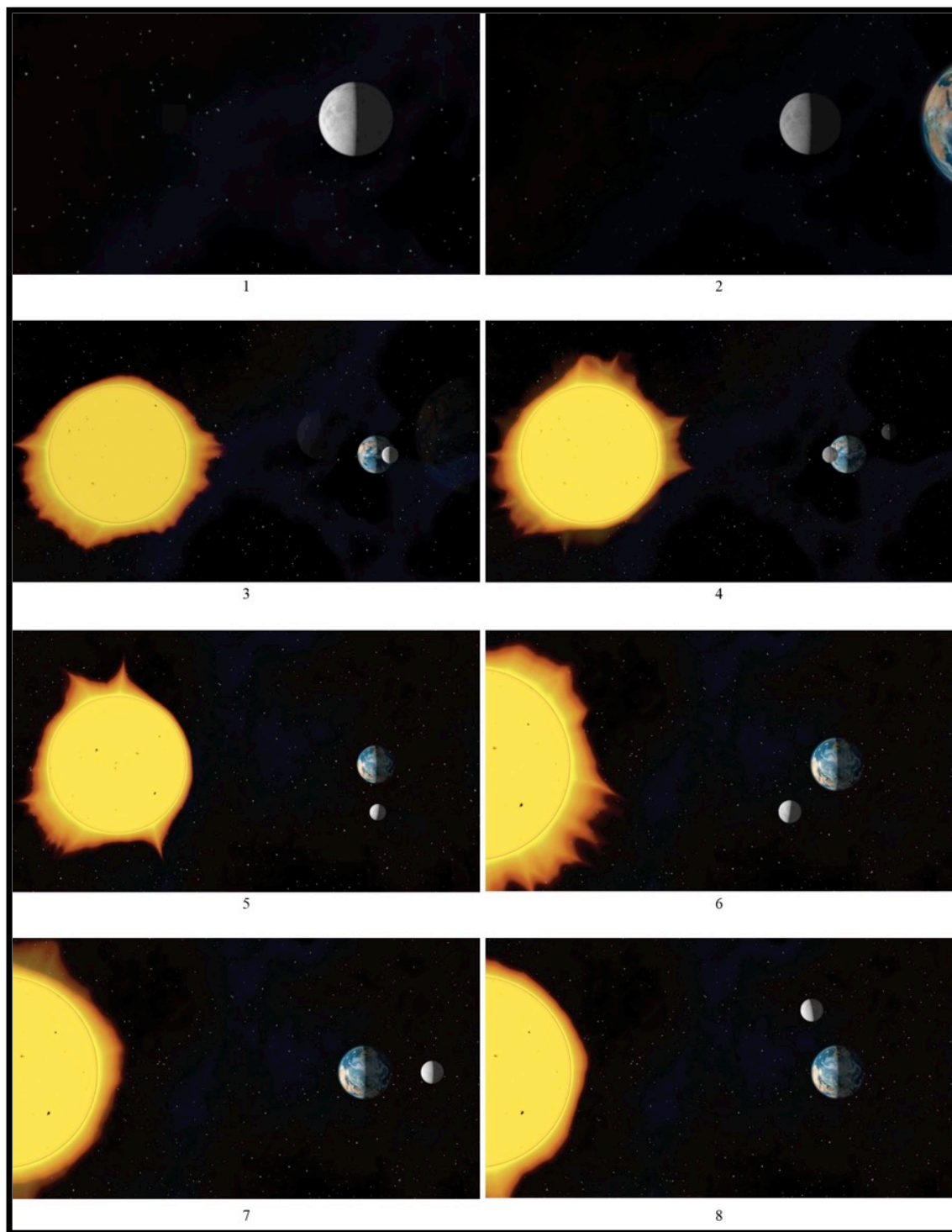


Figure 28. First attempt animation storyboard



*Figure 29. First attempt animation final renders*



## Second design iteration

For the second animation trial I was eager to try to visualize two different viewpoints: the space viewpoint, where we can watch how the moon orbits the earth with only one illuminated half of the moon, and the viewer-on-Earth viewpoint, where people can view each actual phase. Then, I created my storyboard based on this concept (Fig 30). Later on I created a camera movement and transition between the two different points of views.

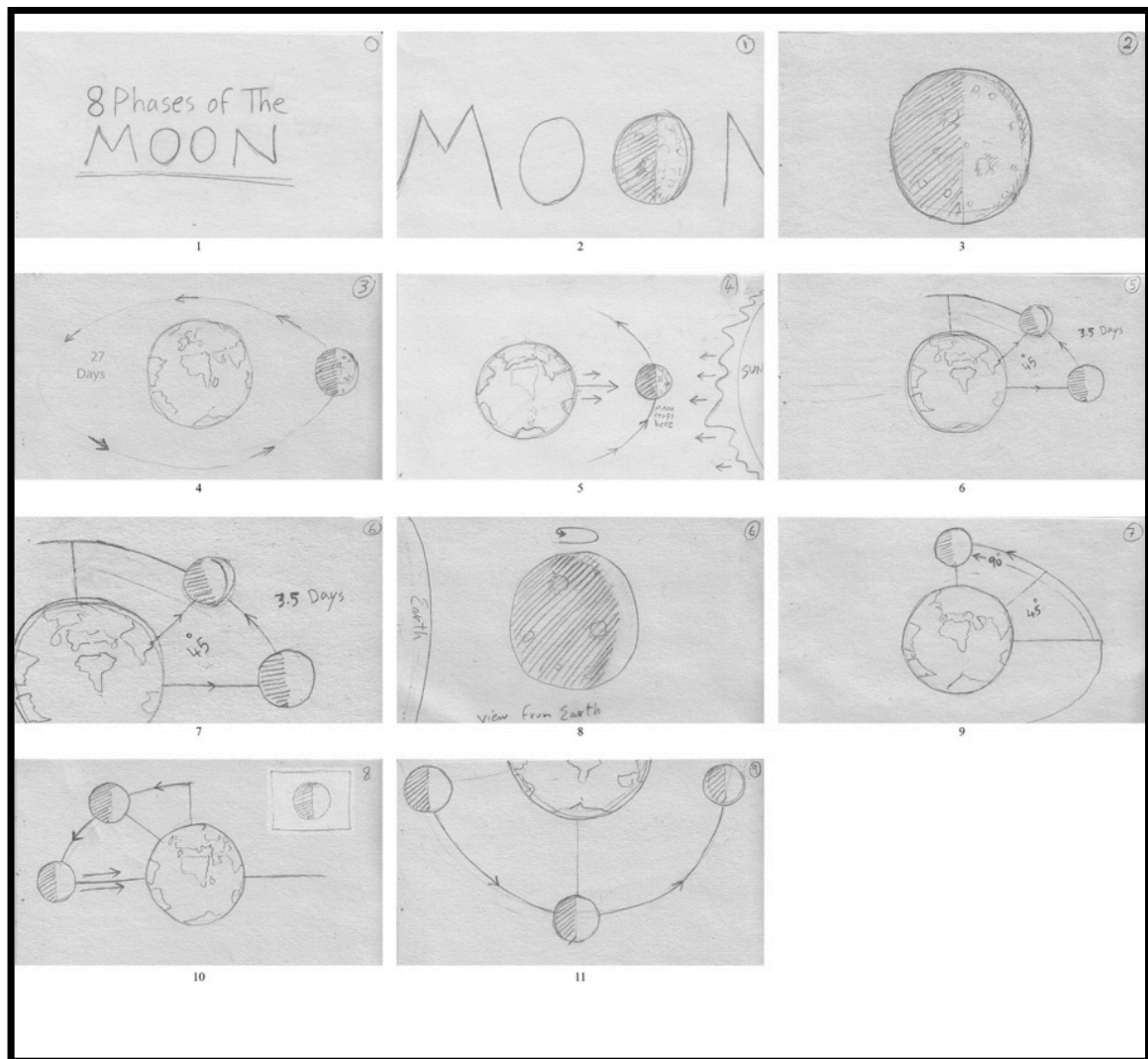
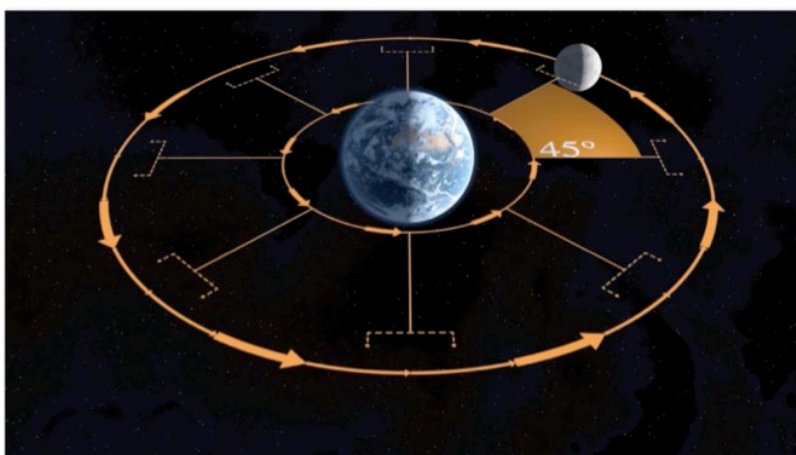


Figure 30. Second animation storyboard

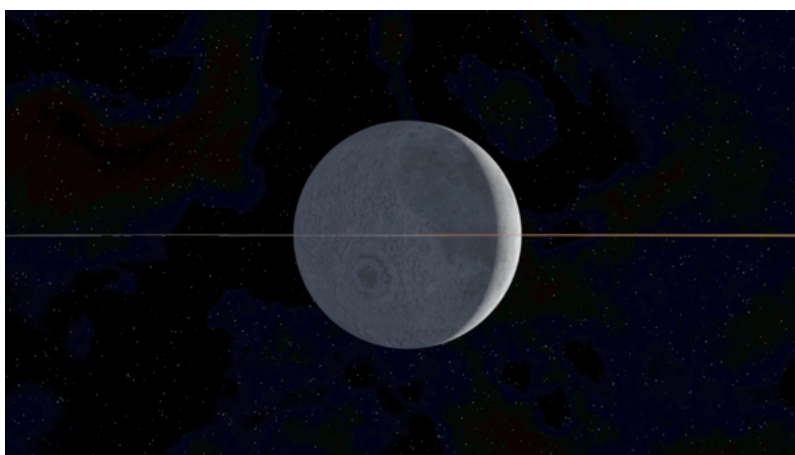


As I became more comfortable using the computer 3D animation software, I created the camera movements that I needed to clarify the process and to show how the moon looks in the Waxing Crescent phase (where the moon is positioned between the earth and sun at a 45-degree angle). I used the two different points of view: the space view (Fig 31), where we see the moon in the middle between the earth and the sun, and the viewer-on-Earth point of view, where we can see the Waxing Crescent moon phase (Fig 32).



*Figure 31. Waxing Crescent phase "space view"*

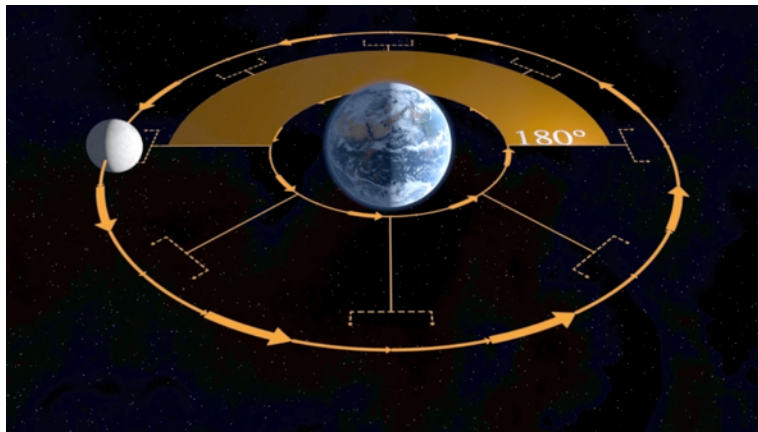
The moon positioned between the earth and sun at a 45-degree angle



*Figure 32. Waxing Crescent phase "viewer-on-earth" point of view*

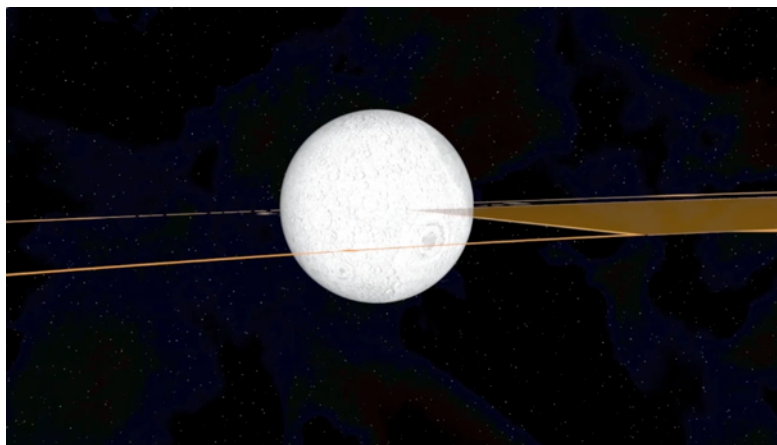
In the second trial I also added a second camera movement in the animation that was not created during the storyboard. This time the camera moves again, between another two different points of view: the space view, where we see the earth in the middle between the moon and the sun (Fig 33) and the viewer-on-Earth point of view, where we can see the full moon (Fig 34). Screen shots of final renders of all the final animations are shown in (Fig 35) and (Fig 36). The final animation can be found on the following online link:

<https://vimeo.com/148544718>



*Figure 33. Full Moon phase: “space view”*

The earth positioned between the moon and sun and the moon at a 180-degree angle



*Figure 34. Full Moon Phase: “viewer-on-earth” point of view*



*Figure 35. Second and final animation, final renders*

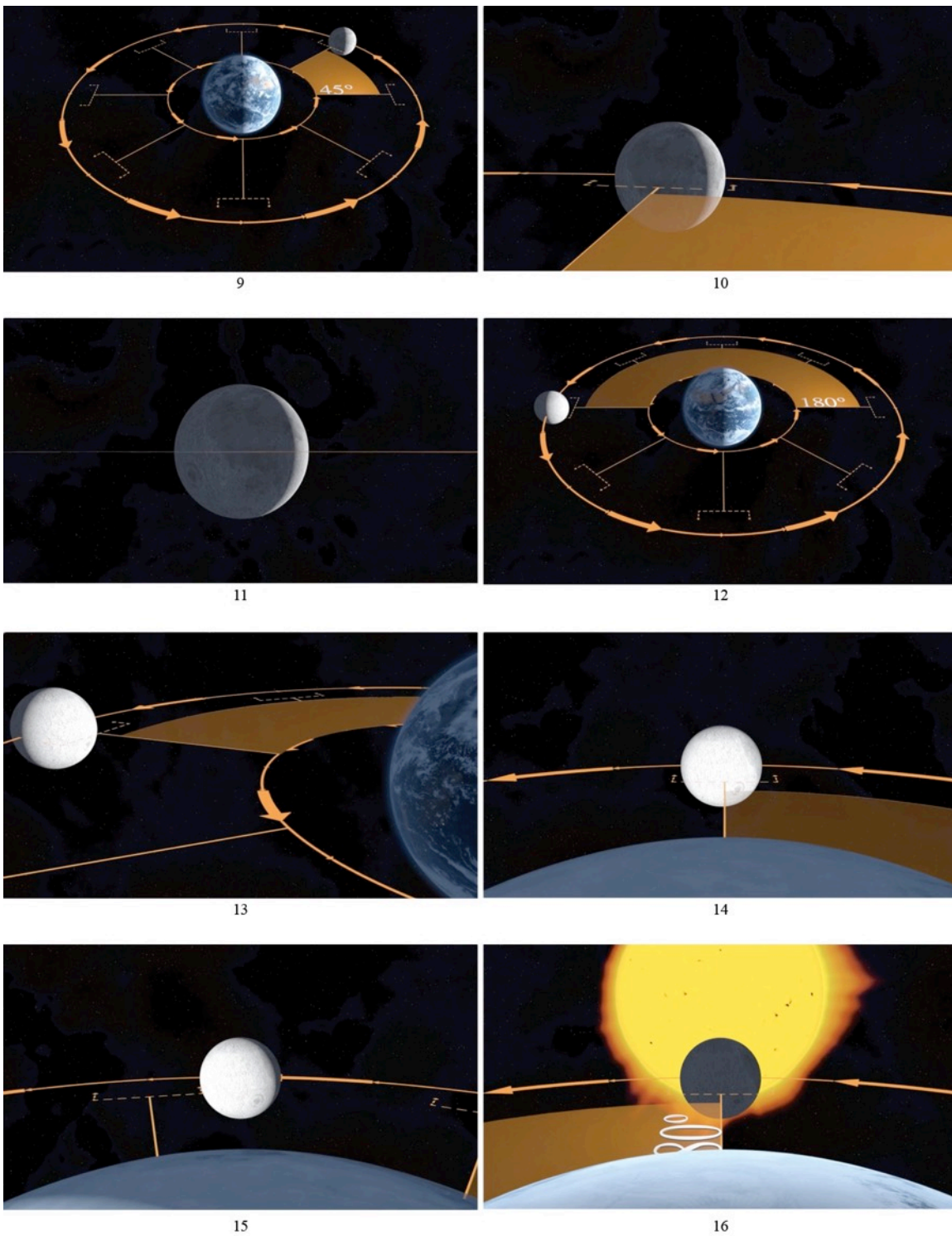


Figure 36. Second and final animation, final renders continue

### **3.2.4 Creating the static format**

#### **First static format design**

For the first static format, I started designing from my original, detailed poster about the moon eclipse and 8 moon phases (Fig 27). I used a similar vertical orientation for the static format because of the normal expectations for a poster orientation. However, the introduction and title were copied exactly to match the introduction narration in the animated format.

#### **Typography and visual elements**

In order to have a similar visual look, I tried to isolate variables of the animated format using the same visual elements. The same typefaces and fonts used in the animated format were used to create the large title for the static format. The main diagram of the moon phases was positioned underneath, combined with the narrations from the animated format in a text format (Fig 37). Some additional text was added to improve the comprehension in the static format.





Figure 37. First version of the "Static Format"

**Second static format design**

For the accuracy of the testing results I was advised to eliminate any additional text that described the moon's phases in the static format and did not exist in the narration of the animated format. So, the text and data explaining each moon phase were edited again to match exactly the narration in the animated format (Fig 38). Only some text that explained the diagrams was left in the static format to help for diagram clarification. Other diagram elements from the animated format were added to the static format in order to match perfectly and create a similar visual experience between both the Static and Animated formats. This appears in the wedges around the earth, which divided the moon orbit into separate degree areas to facilitate the description of the process. Also, a small box was added to contain some extra narrations from the animation.

The main difference in the second static format is that all the text that describes the eight different moon phases matches exactly the narrations in the animated format.



Figure 38. Second version of the "Static Format"



Figure 40. Final design of the “Static Format”

### **3.2.5 Creating consistency**

#### **(Design terminology/naming conventions)**

On finalizing the second design a naming convention for the name of the moon phase number 3 (Half Moon) arose. The name (Half Moon) seems appropriate to its own phase shape (Fig 39); however, I found that the name has been used interchangeably with the name (First Quarter) for the same phase in more than one source. There is another phase similar in appearance to the (Half Moon) phase, which is the “Third Quarter” phase where the other half of the moon appears to be fully illuminated too. I decided to use the naming system for the moon phases provided by The University of Nebraska-Lincoln astronomy education group as the main naming reference for the moon’s phase names in this project. The final change is the “Half Moon” name changed to “First Quarter” and the “Third Quarter” name remained as is, same as our main naming reference (knowing that some other references name it the “Last Quarter”).

#### **Consistency with the animated format**

In order to keep similarity in the animation narration, I changed the names in the narration of the animated format too. The voice narrations were recorded again to match the static naming adjustments of the moon phases and imported into the video animation again.

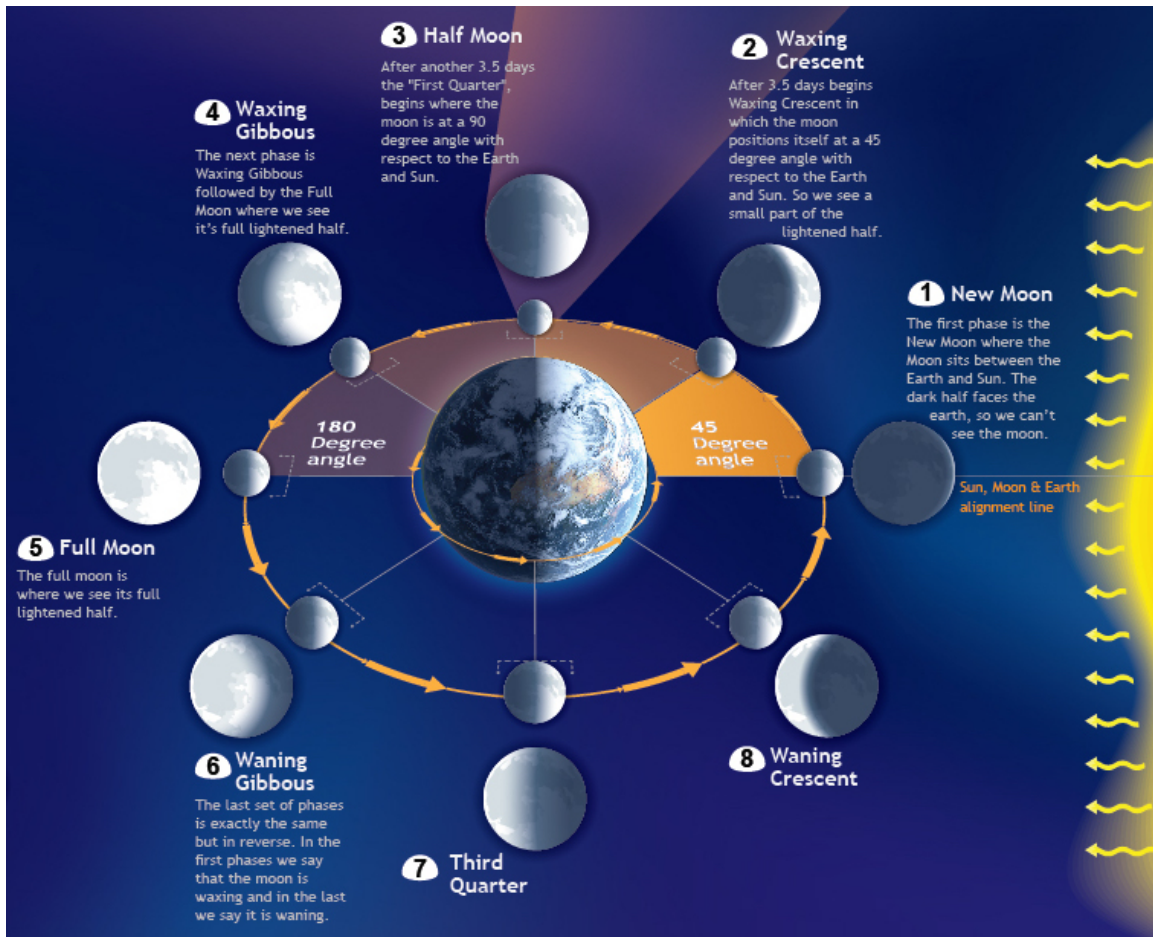


Figure 39. "Half Moon" Phase number 3 and "Third Quarter" Phase number 7

### 3.3 Participants

All participants were divided into two groups: Group A, which tested on the animated format and Group B, which tested on the static format. Each group consisted of 15 participants. Group A participants were in the age range from 18-23 with different majors like Aerospace Engineering, Biology, Animal Science, High School Graduate, Pre-Health Program, Agriculture Business and Kinesiology. In Group B twelve participants were in the age range of 18-23, two participants in the age range of 24-29 and one from the age range 36-41 with different background majors like Graphic Design, Software Engineering, Microbiology, Computer Science, Psychology, Agriculture Business, Animal Science, Kinesiology, Food Science and Animal Ecology.

Many of the participants in both groups were from STEM related majors. This was an effective contributing factor for the accuracy of the results and toward a better evaluation of the infographic effectiveness in communicating science subjects. Most of the participants were comfortable in using the computer and watched online videos on a daily basis. However, most of them rarely used print magazines and newspapers (static format), using them either on a weekly or less than monthly basis.

In addition, all participants stated that they found both formats of the infographic to be engaging and informative, and it was really useful in helping them comprehend the subject. Nevertheless, as will be shown in the next analyses section, participants were able to have higher correct scores in the medium they used less often, the Static Format.

### **3.4 Testing Procedure**

For the testing procedure and to ensure accuracy as much as possible personal one-on-one testing sessions were conducted. Participants were recruited by word of mouth and flyers from multiple locations on and outside campus to participate in a research study on the efficacy of using infographics as a teaching aid framework and visualization for complex science subjects. The study was conducted mostly in class and study rooms where the environment was quite and suitable for the test.

#### **3.4.1 Test format**

All students who participated in the research study were tested about their previous knowledge and experience of the topic (Phases Of The Moon) through a pre-test survey of four questions (Appendix D). The pre-test was effective because it provided a measure of the participant's previous knowledge about the subject. Each participant was then randomly provided with either the animated format (Group A) to watch or the static format (Group B) to view and read. Both groups were then provided with the exact same post-test survey questions to answer (Appendix F).

#### **Group A**

Participants provided with the animated format (Group A) were given unlimited time and allowed to play, replay, stop or move forward the video as many times as they needed to feel comfortable in understanding the subject. The animation was designed on a high definition video format (HDV-1280X720 Pixel) and played on a 13.5-inch computer screen. Participants were also provided with earphones or headphones in order to provide a distraction-free and clear listening experience during the test.

## **Group B**

Participants provided with the static printed format (Group B) were given the 11X17-inch printed static format, and unlimited time, to read and study the data and information for as long as they needed, to feel comfortable in understanding the subject.

Both groups were informed to be ready to answer a post-test survey of five questions about the subject. The post-test survey questions are completely different than the pre-test questions.

### **3.4.2 Consent form**

As part of the procedure to protect the human participants, the Institutional Review Board (IRB) at Iowa State University reviewed the process of this thesis study (Appendix A).

Accordingly, a consent form (Appendix B) was required to be read and signed by the participants showing them the purpose, procedures, benefits, costs, risks if any and compensation. The participants were informed that there would be no compensation for their participation, however their contribution will help in the research for developing effective educational frameworks based on infographic design.

### **3.4.3 Demographic form**

A demographic form (Appendix C) was devised and presented to the potential participants. The reason for the form questions was to collect demographic data and educational back-grounds from the participants to ensure a wide variety of the participants. As most of the testing took place on the Iowa State University campus, I wanted to make sure that participants were from a variety of educational backgrounds (majors) to ensure no bias in the data. Thirty adults, fifteen for each group (Group A tested on the animated format, Group B tested on the static format) age 18 years old and

older were tested on the infographics from the educational majors of Animal Science, Engineering, Computer Science, Food Science, Kinesiology, Agricultural Business, Psychology, Microbiology, Software Engineering, Design and non-college students participants. All the detailed demographic data of the participants can be found under Appendix L & Appendix M. The testing sessions and collection of the data were done during the spring semester of 2016.

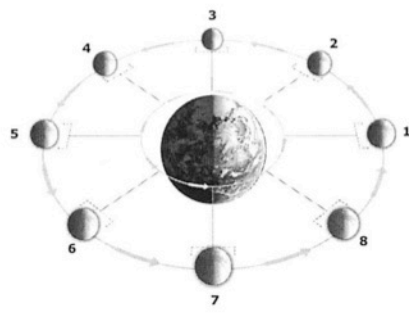
#### **3.4.4 Survey questions and evaluation procedures**

Two different survey questions were designed to serve as the evaluation measures of the study on using infographics to help teach a complex science subject (Phases Of The Moon). The pre-test survey (Fig 41) consisted of four different questions and the post-test survey (Fig 42) consisted of five different questions. The first three questions were multiple-choice format. The fourth question provided an illustration of a divided moon shape into four wedges, asking the participants to shade a specific moon phase. The final question in the post-test simply asked for any feedback about the study. The pre-test and post-test questions, as aforementioned, were assembled of different questions and each served a specific purpose.

The pre-test was testing any previous knowledge about the topic and the post-test was testing the effectiveness and learning outcome from the infographics. The detailed pre and post-test can be found under Appendix D & Appendix F.

**Attachment 8. Pre-Test Questionnaire**


1. Please circle the moon's position for the **First Quarter** phase ?



2. Approximately how many days does it take the moon to orbit the earth?

26      27      28      29      30

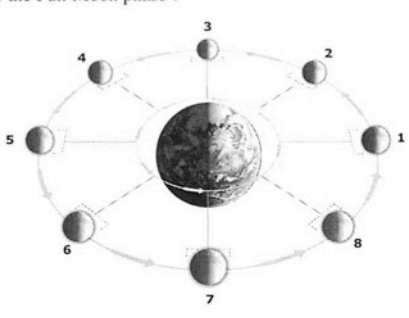
3. Which of the below is a quarter moon (Waning Crescent)?



*Figure 41. The pre-test survey questions 1-3*

**Attachment 9. Post-Test Questionnaire**


1. Please circle the moon's position for the **Full Moon** phase ?



2. At what degree is the moon when **Waxing Crescent**?

25      35      45      60      90

3. Which of the below is a Waxing Gibbous moon?



*Figure 42. The post-test survey questions 1-3*



#### **3.4.5 Data analysis**

After collecting the answers and demographic data from the survey question's, the data was grouped and organized by creating four different tables containing all of the questions with each group's right and wrong answers and any demographic information. The detailed analysis and explanations can be found in Chapter Four.

## CHAPTER 4. ANALYSIS AND RESULTS

### 4.1 Data

#### 4.1.1 Data sorting

After collecting the surveys from the participants, I analyzed and sorted the data by using Excel and other spreadsheets to be able to visualize the data and find any correlations.

First, I created two tables (Table 4.1 for Group A- Animated) and (Table 4.2 for Group B-Static) to sort the participant's demographic data and majors, and to separate the total number of each group's correct and incorrect answers for both the pre-test survey questions and the post-test survey questions.

Secondly, I created three large tables (Appendix E), (Appendix G) and (Appendix H) for the pre-test and post-test data, containing all 30 participants (15 participants of Group A and 15 participants of Group B) including their correct and incorrect answers for each question of the four-question survey. These tables were created in order to help sort, group and visualize each question's level of difficulty by the number of correct and incorrect answers and to discover any correlation between the question's ability to be answered correctly with the format (Static or Animated) used in the test.

**Table 4.1** Group A (Animated Format) results

Participant	Major	Age Group	Pre Test		Post Test	
			No. of Correct Answers	No. of Incorrect Answers	No. of Correct Answers	No. of Incorrect Answers
1	Aerospace Engineering	18-23	1	3	3	1
2	Biology	18-23	1	3	3	1
3	Biology	18-23	1	3	3	1
4	Animal Science	18-23	2	2	2	2
5	Biology	18-23	2	2	4	0
6	Animal Science	18-23	2	2	3	1
7	Animal Science	18-23	2	2	2	2
8	High School Graduate	18-23	1	3	2	2
9	High School Graduate	18-23	1	3	1	3
10	Pre-Health Program	18-23	0	4	0	4
11	Agriculture Business	18-23	1	3	3	1
12	Animal Science	18-23	3	1	1	3
13	Agriculture Business	18-23	1	3	1	3
14	Animal Science	18-23	1	3	2	2
15	Kinesiology	18-23	0	4	1	3
<b>Total</b>			<b>19</b>	<b>41</b>	<b>31</b>	<b>29</b>

**Table 4.2** Group B (Static Format) results

Participant	Major	Age Group	Pre Test		Post Test	
			No. of Correct Answers	No. of Incorrect Answers	No. of Correct Answers	No. of Incorrect Answers
1	Graphic Design	36-41	1	3	3	1
2	Graphic Design	24-29	1	3	3	1
3	Software Engineering	18-23	1	3	1	3
4	Microbiology	18-23	2	2	3	1
5	Computer Science	18-23	1	3	3	1
6	Psychology	18-23	1	3	4	0
7	Agriculture Business	18-23	3	1	3	1
8	Graphic Design	24-29	1	3	3	1
9	Graphic Design	18-23	1	3	2	2
10	Animal Science	18-23	1	3	2	2
11	Animal Science	18-23	2	2	1	3
12	Kinesiology	18-23	0	4	2	2
13	Food Science	18-23	2	2	1	3
14	Animal Ecology	18-23	2	2	2	2
15	Computer Science	18-23	2	2	4	0
<b>Total</b>			<b>21</b>	<b>39</b>	<b>37</b>	<b>23</b>

## 4. 2 Data Analysis & Results

### 4. 2.1 Overall scores

After analyzing the data the results were used to answer the following questions:

1. Is there an overall improvement in the scores of the post-tests of both groups to prove the efficacy of both formats of the Infographic in helping with the comprehension of the complex science topic?
2. Which Infographic format is the most effective in communicating the topic and has the higher correct scores?
3. Do some questions show themselves to be more difficult or easier to understand than the others depending on the format used in the test (Static or Animated)?

**Table 4.3** Pre and Post Test scores for both groups A and B

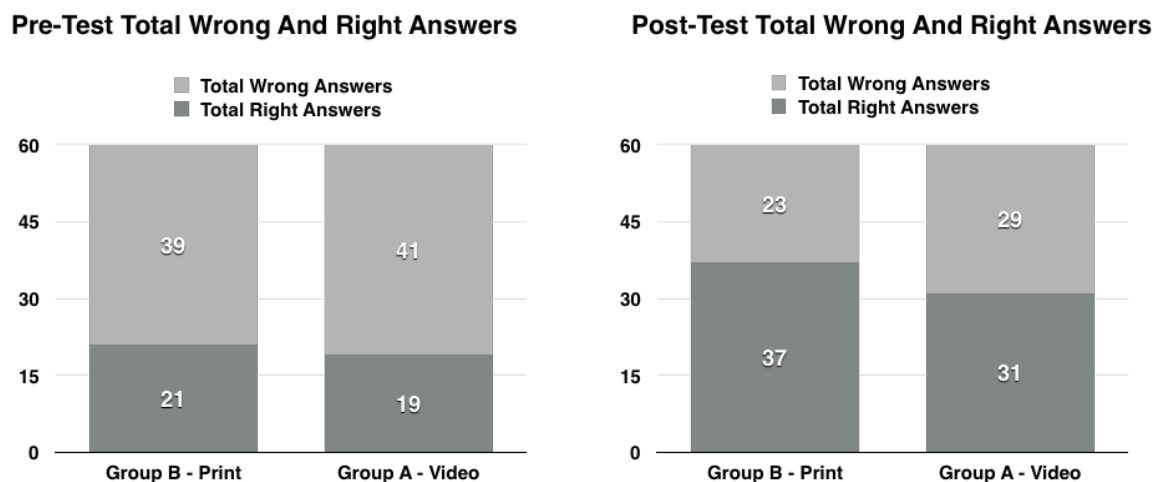


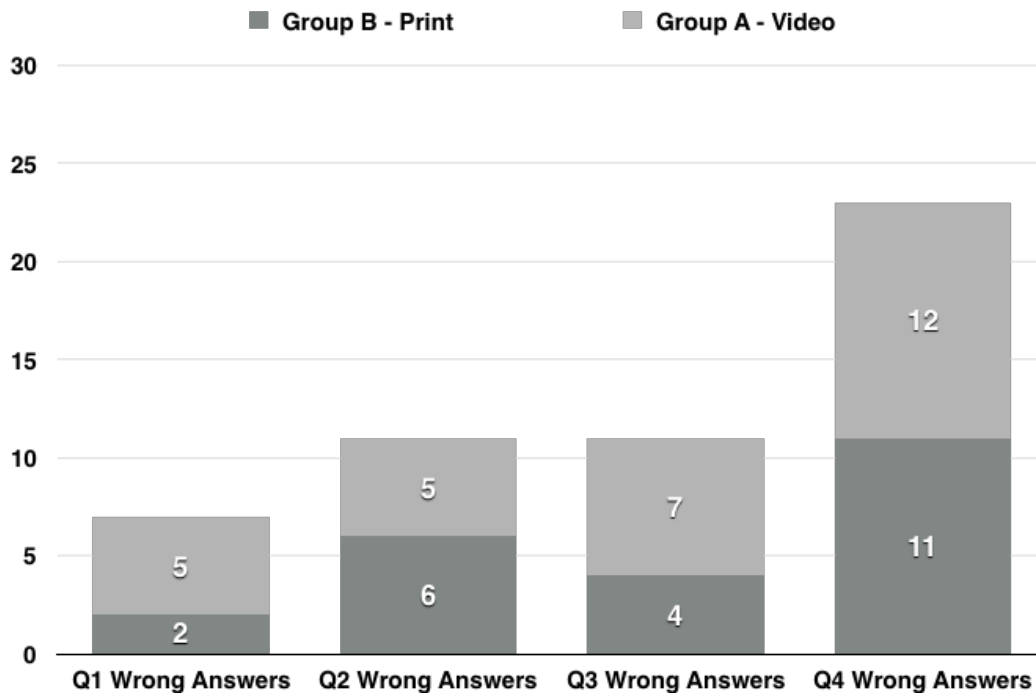
Table 4.3 shows a significant increase in the total correct scores of both groups, A and B, in the post-test. The correct scores of Group A increased from 19 to 31 and Group B from 21 to 37, which indicated a better comprehension of the subject after reading or

watching the infographics. Although the pre-test correct scores for both groups were nearly the same, with 21 and 19 correct answers for Group B and Group A respectively, the post-test scores show a large increase in the correct answers in favor of Group B, with 37 correct answers compared to 31 correct answers for Group A.

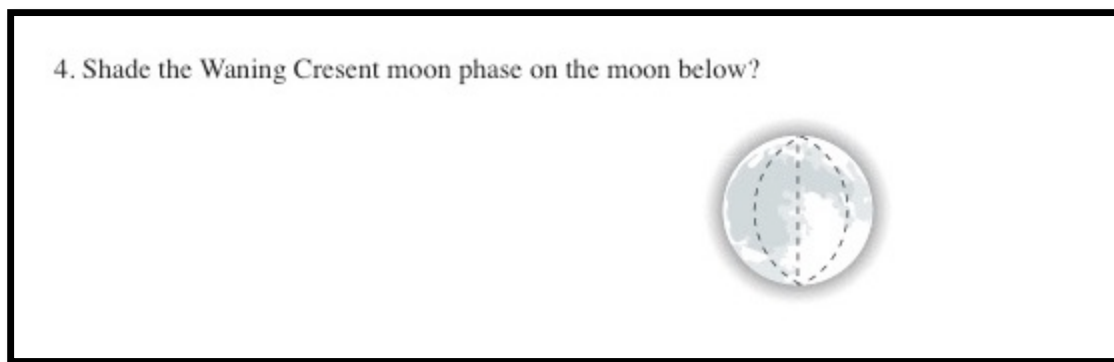
To sum-up, the total number of correct answers in the post-test for both groups increased to reach 68 with a percentage of 57% compared to only 40 correct answers (33%) in the pre-test. Thus, both infographic formats proved to be significantly effective in improving comprehension and increasing retention of the topic (Phases Of The Moon), knowing that the post-test questions were completely different than the pre-test questions.

#### 4. 2. 2 Incorrect scores

**Table 4.4** Post-Test Groups A and B Incorrect Answers



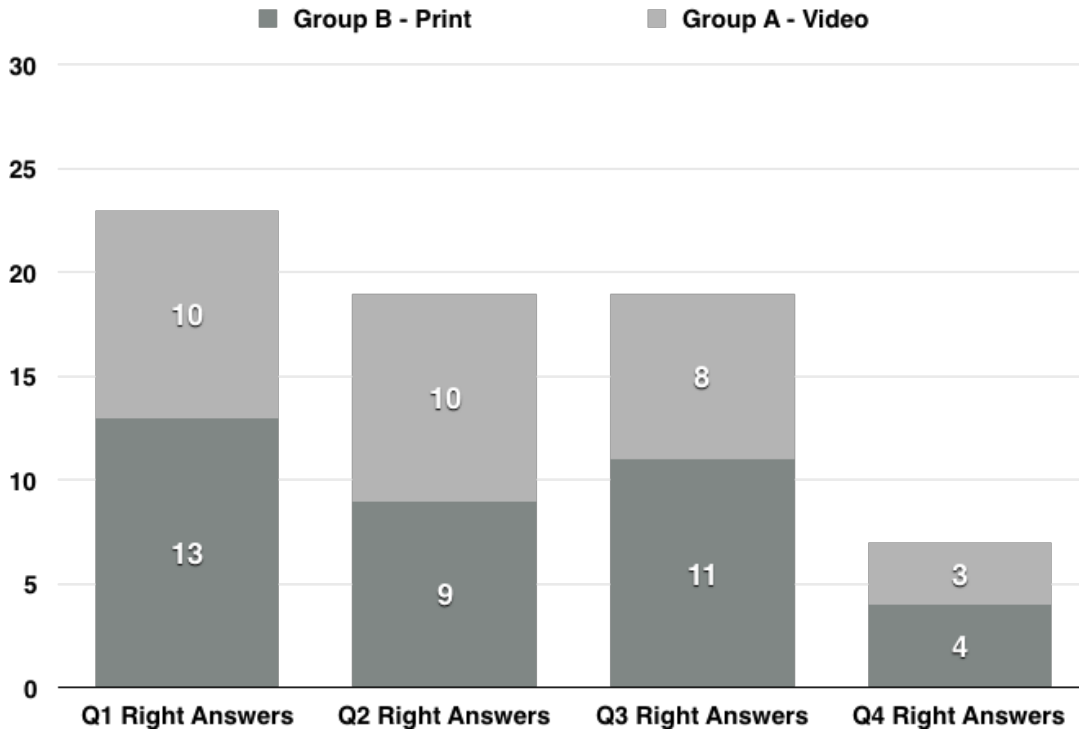
A look at the scores for the incorrect post-test questions, it is clear that question four has the largest number of incorrect answers in both formats. In Table 4.4 Groups A and B both struggled in answering this question, as 12 out of 15 participants from Group A (Animated Format) answered this question incorrectly, while 11 of 15 participants from Group B (Static Format) also answered this question incorrectly. Looking at the question format and diagrams as they appear in Appendix D and F, I believe that the way the question was constructed and the sectioned moon illustration was depicted confused most of the participants (Fig 43). This will be discussed further in the limitations section. Participants struggled to determine which section they should be shading to represent the moon phase name they were asked to identify (the lighted part that they view from earth or the dark part of the moon so that the lighted part can appear)? However, the static format still had the least number of incorrect answers for this question, which supports the better effectiveness of the static format again. Answers for question number four, which shows how each participant shaded the moon, can be found in (Appendix K).



*Figure 43. Question number four (Post-test survey)*

#### 4. 2. 3 Correct scores and questions one and two advancement

**Table 4.5** Post-Test Groups A and B Correct Answers



Looking at the post-test correct answers in Table 4.5, it is clear that Group B (Static Format) has the largest number of correct answers with a total of 37 as mentioned above. Moreover, Group B scored more correct answers in each question except in question two.

Question One had the most correct answers in the post-test with a total of 13 correct out of 15, I believe this is because question one provided a similar illustration to the one used in both formats of the infographic and asked participants to circle a specific moon phase location on the illustration, so participants were able to easily recall the visual graphics used in the designs and scored more correct answers. Question Three also scored a larger number of correct answers with 11 correct out of 15 questions. Overall,



this implies again the better effectiveness of Group B (static format) in its ability and efficacy in communicating the complex science subject (Phases of the Moon) over the animated format.

Nevertheless, question two was the only question that had the most correct answers by Group A (Animated Format) comparing to the other three questions, where the largest numbers of correct answers belong to Group B (Static Format). Question two is the only question where its answer was revealed in both the verbal (video narration) and the visual (graphics) of the animated format. (The required answer was actually visible in the video; the motion graphic shows the Waxing Crescent occurring at 45-degree angle with the number 45 appearing as a text and the narration verbalizing the same information simultaneously). Thus, adding both verbal and visual information can play a critical role in improving the effectiveness of the infographic. I believe that the animated format could have completely exceeded the printed static format in the overall comprehension and effectiveness in teaching if all of the information and data had been portrayed in audio, text, and visual; and if the survey questions had been formatted in a more simplistic style or if more participants watched the animated format more than once. This might have resulted in more correct answers and consequently better comprehension.

### **4.3 Limitation of the Methodology**

Some limitations were observed during the testing process and analysis of the data. Those limitations may or may not have a slight effect on the accuracy of the results.

#### **Scientific content accuracy**

The animation and graphics designed for the project were not thoroughly scientifically accurate. Some extra complex details like the earth tilting degree and the moon's orbit tilting degree were discarded in order to focus only on the moon's different phases and to simplify the graphics. Also, some unrealistic features were added in the animated format for the sake of creating visual interest like showing the moon rotating around itself in the first scene.

#### **Survey questions' clarity**

During the testing process, the clarity of question number four in both the pre- and post-test surveys appeared to be an issue. The way the question was constructed and the way the sectioned moon illustration was depicted, (aforementioned in chapter three), confused some participants about which part they should be shading to represent the moon phase they were asked to identify? Reasons for confusion with this question were not deeply analyzed and investigated. Answers to this question can be found on (Appendix K).

#### **Data Analysis**

As the main purpose of this thesis was to focus on how effective the different formats of the infographic were on helping participants learn and comprehend the science subject

(Phases Of The Moon), the data analyzed focused on the question's correct and incorrect answers in both formats and in the pre- and post-test. No correlations were made regarding other demographic questions such as gender, age, or major. However, participants from various gender and study majors were recruited/requested for the test in order to ensure participant diversity and to avoid testing only participants with Art and Design backgrounds where they may have superiority in comprehending visually oriented information designs than others.

### **Participants**

There were only 30 participants; 15 in each group. Although this number was sufficient to create a considerably good analysis of the data, the analysis and results of the study would have been richer if the sample size were larger. Moreover, the tested participant's demographic data showed that nearly all of the participants (29 out of 30) were Midwestern, educated young adults in the age group between 18-30 years old. Although this age group is perfect for testing the effectiveness of infographics in helping them learn, a younger age group, primary and secondary school students, would have been valuable too because a primary reason of this study is to help advance learning in the STEM field. Any future work in regard to this study will take into consideration the previous limitations.

## CHAPTER 5. CONCLUSION

In summary, my findings verify that both formats of the infographic, the animated and the static, were effective in increasing the knowledge and comprehension of the subject for both groups A and B. They do not, however, support my hypothesis, which predicted that the animated format would be more effective than the static format.

Participants in both groups were able to score more correct answers in the post-test questions reaching a higher figure of 68 correct answers out of 120 possible answers after reading or viewing the infographic. Compare this to the pre-test score of only 40 correct answers for both groups out of 120. Thus, infographics have the potential to be helpful in the teaching of the subject with a significant increase in the percentage of correct scores from 33% to 57%.

A possible reason for this could be that the visual explanation and graphics viewed by the participants were really engaging and created both a visual interest and provided compelling data about the subject. This explanation appears through the feedback and comments provided by most of the participants in (Appendix I) and (Appendix J). Participants said that overall they found the infographics to be informative and helpful. Thus, they were able to comprehend and understand how to identify the different moon phases and other related data. This conclusion reinforces the results of Multiple Intelligence Theory and Neil Fleming's VAK Model, where it was found that humans learn and comprehend information through three types of stimuli: Visual, Auditory, and Kinesthetic or Tactile. The infographics used in my study offered a visual stimuli (Static Infograph) and a visual, auditory, and kinetic stimuli (Animated Infograph).

My hypothesis predicted that an animated format infographic would be more effective in communicating this complex science subject (Phases Of The Moon) than the static one. This was due to the previously mentioned studies in Chapter Three about the deficiency of the static format. However, despite my hypothesis the static format proved to be more effective in communicating the subject and as a teaching-aid framework with a higher score in the post-test of 37 correct answers out of 60 by Group B compared to 31 correct answers by Group A. Moreover, Group B scored more correct answers in each question of the post-test than Group A, except question two as mentioned in Chapter four “Data Analysis & Results”.

Reasons for the superiority of the static format could be that the static format provided the participants with the flexibility to visually navigate the entire poster graphics and text, back and forth over the different phases, and have access to all of the information provided at the same time. Participants were able to read the text and view the graphics simultaneously until they completely comprehended each phase or a specific part of the infographic. Peters, D. (2013) states that using a series of static images when learning conceptual processes is more effective than using animation. Learners can discover relations much more easily between static images as long as they are viewing them at their own pace and consequently improve their learning outcome. Animation seems to provide the learners with too much data, blocking their minds from making their own reasoning. Also, in studies by Mayer et al. (2005), static formats proved to deliver a better learning experience over the animated one when comparing retention measures, even when both formats used the same information.

Secondly, the video format is a linear system which means information is presented in a sequential system. Participants viewed the video from the beginning to the end. They had the ability to play, pause, stop and repeat the video as much as they wanted. However, only two to four participants did replay the animation (I did not track this), most did not replay the video animation, watching it only one time and commenting it was really interesting and informational.

In conclusion, while the animated format tried to solve the deficiency of the static format by providing the viewer with a visual solution (the camera movement as aforementioned in chapter three “The Methodology”) to view the moon phases from two different perspectives continually without breaking the viewer’s line of sight, the static format remained to be the most effective medium for communicating and teaching this complex science subject (Phases Of The Moon). In addition, despite the fact that most Group A participants enjoyed watching the video infographic according to their comments, the comprehension ability, information retention and scores of Group B “Static Format” were much better.

### **Future work**

In further study of this thesis topic “Phases Of The Moon As A Complex Science Subject” or on further study of the overall efficacy of infographics as a teaching aid framework, there are some things that I would like to adjust and try. The first would be using a different age group, like twelve or thirteen year olds, or the specific grade level where they are exposed to the science topic “Phases Of The Moon” for the first time. The results would be more related and effective to the main purpose of the study. Secondly, I

would reformat or change question four in both the pre-test and post-test to make sure it is not confusing for participants to understand and answer. Moreover, I would create a more scientifically accurate animation and graphics to ensure that the content is complying perfectly with other authentic, scientific material related to the topic, so it will not cause any confusion. The last addition would be to have more textual data in the video to support and accompany the narrations as this was proved to be very effective in helping participants learn, as evident in the results of question two in the post-test.

Another important thing that I would like to create and test would be adding more advanced technical capabilities, like interaction, to the computer animated format or creating an interactive version that utilizes both animated and static graphics depending on which format would communicate a specific phase or part more effectively.

Adding interactive features to the video would have created an easier and better experience for the viewers to control the way they played the video infographic. This should encourage participants to rewind, replay and navigate the computer animation more. Based on my observations, only two or four participants played the animated format (video) twice (I did not track this) or paused at a specific point. Interaction would create a better overall learning experience and consequently improve comprehension and information retention; leading to better results. A possible design improvement in an interactive version could be creating a separate button for each moon phase, where viewers can choose based on their level of comprehension and understanding of a specific part or phase. Providing the viewers with a navigational system through the various phases of the scientific topic would be really useful in the testing phase to see how interactive abilities would improve comprehension.

**Future implications**

The results of this study and any other possible future work would be of great significance to textbook publishers and multi media publishers overall. Questions like why printed static media are more or less useful than other media formats would be answered and assist in creating the best possible media for learning. In addition, studies using different scientific topics whose comprehension may also require both spatial and temporal data can be conducted. For instance geology, biology, evolution and the spread of trends and diseases are subjects that would be a valuable addition to the studies of this thesis, which may add to the advances of the STEM education field.

Furthermore, information graphic designers who have not explored animation would benefit greatly from this study; graphic designers have a reputation of working mainly for the commercial world, so designers could be encouraged to use their information design and visualization skills towards science education (STEM). Moreover, a great benefit of this research could be the validation of the use of infographics in STEM education, as well as a contribution graphic designers can make to advance the STEM education field.



## APPENDIX A. IRB APPROVAL FORM

IOWA STATE UNIVERSITY  
OF SCIENCE AND TECHNOLOGY

Institutional Review Board  
Office for Responsible Research  
Vice President for Research  
1138 Pearson Hall  
Ames, Iowa 50011-2207  
515 294-4566  
FAX 515 294-4267

Date: 1/19/2016

To: Hesham Hassan  
146 Design

CC: Dr. Paul R Bruski  
158 College of Design

From: Office for Responsible Research

Title: Phases of the Moon

IRB ID: 15-696

Approval Date: 1/15/2016

Date for Continuing Review: 1/14/2018

Submission Type: New

Review Type: Expedited

The project referenced above has received approval from the Institutional Review Board (IRB) at Iowa State University according to the dates shown above. Please refer to the IRB ID number shown above in all correspondence regarding this study.

To ensure compliance with federal regulations (45 CFR 46 & 21 CFR 56), please be sure to:

- **Use only the approved study materials** in your research, including the recruitment materials and informed consent documents that have the IRB approval stamp.
- **Retain signed informed consent documents for 3 years after the close of the study**, when documented consent is required.
- **Obtain IRB approval prior to implementing any changes** to the study by submitting a Modification Form for Non-Exempt Research or Amendment for Personnel Changes form, as necessary.
- **Immediately inform the IRB of (1) all serious and/or unexpected adverse experiences** involving risks to subjects or others; and (2) **any other unanticipated problems** involving risks to subjects or others.
- **Stop all research activity if IRB approval lapses**, unless continuation is necessary to prevent harm to research participants. Research activity can resume once IRB approval is reestablished.
- **Complete a new continuing review form** at least three to four weeks prior to the **date for continuing review** as noted above to provide sufficient time for the IRB to review and approve continuation of the study. We will send a courtesy reminder as this date approaches.

Please be aware that IRB approval means that you have met the requirements of federal regulations and ISU policies governing human subjects research. **Approval from other entities may also be needed.** For example, access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **IRB approval in no way implies or guarantees that permission from these other entities will be granted.**

Upon completion of the project, please submit a Project Closure Form to the Office for Responsible Research, 1138 Pearson Hall, to officially close the project.

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.

## APPENDIX B. CONSENT FORM

ISU IRB # 1	15-696
Approved Date:	15 January 2016
Expiration Date:	14 January 2018

**Attachment 5. Infographic Evaluation: The Moon Phases****Informed Consent Document**

Title of Study: **Infographic Evaluation**  
 Participants: Principle Investigator: Hesham Hassan  
 Faculty Supervisor: Paul Bruski, BFA, MFA

This is a test studying on infographics efficacy. Please take your time in deciding if you would like to participate.  
 Please feel free to ask questions at any time.

**INTRODUCTION**

The objective of this study is to determine the efficacy of using static or animated infographics in communicating complex science subjects.

This study aims to help designers and educators determine the proper and best solutions in creating teaching aid materials for science subjects in order to advance the learning curve and help student's comprehend complex topics through a less stressful and visually interesting medium that would also help in increasing information retention.

This usability study will help to create the most effective teaching aid materials for education.

Participants will not get direct benefits. However, this knowledge can be expected to ultimately provide significant opportunities to improve usability of interface system for general public.

**DESCRIPTION OF PROCEDURES**

If you agree to participate in this study, participation will last for approximately 35 minutes.

During the study you may expect the following study procedures to be followed.

- 1) The researcher will contact prospective participants to schedule a testing study and will send informed consent document.
- 2) On the selected date of the testing study, you will be given a copy of the Informed Consent Document for review and to sign prior to the start of the session. If you agree, and sign the Informed Consent Document the session will begin.
- 3) Information regarding the project will be read before the session.
- 4) The respondent will complete pre-survey questionnaire regarding demographic information and their familiarity with the technologies.
- 5) The testing study can be done in 35 minutes at your convenience time at the College of Design or other quiet places
- 6) The participants will perform a series of tasks to read and view the infographic design or video. You may skip any tasks that you do not wish to perform or that makes you feel uncomfortable.
- 7) The participants will complete a post-test questionnaire after the testing.

**RISKS**

There are no foreseeable risks in this study. However, you may leave the study at any time without penalty.

**BENEFITS**

Participants will not get direct benefits. However, this knowledge can be expected to ultimately provide significant opportunities to improve the creation of effective (infographics) teaching aid materials.

**COSTS AND COMPENSATION**

You will not have any costs from participating in this study. There will not be any compensation to participate in this study.

**PARTICIPANT RIGHTS**

Your participation in this study is completely voluntary and you may refuse to participate or leave the study at any time. If you decide to not participate in the study or leave the study early, it will not result in any penalty or loss of benefits to which you are otherwise entitled. During the testing, if you feel uncomfortable at anytime you can quit.

**CONFIDENTIALITY**

Records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available. However, federal government regulatory agencies and the Institutional Review Board (a committee that reviews and approves human subject research studies) may inspect and/or copy your records for quality assurance and data analysis. These records may contain private information.

To ensure confidentiality to the extent permitted by law, the following measures will be taken.

The participant's identity will be anonymous all throughout the survey. Only the researchers will have access to the data. The data will be entered and kept in a password-protected computer located on the PI's and CO-PI's computers.

**QUESTIONS OR PROBLEMS**

You are encouraged to ask questions at any time during this study. For further information about the study contact Paul Bruski, Supervisor, phone \_\_\_\_\_, email \_\_\_\_\_, or Hesham Hassan, Principal Investigator,

If you have any questions about the rights of research subjects or research-related injury, please contact IRB Administrator, (515) 294-4566, [IRB@iastate.edu](mailto:IRB@iastate.edu), or Director, Office for Responsible Research, (515) 294-3115, 1138 Pearson Hall, Ames, IA 50011.

\*\*\*\*\*

**SUBJECT SIGNATURE**

Your signature indicates that you voluntarily agree to participate in this study, that the study has been explained to you, that you have been given the time to read the document and that your questions have been satisfactorily answered. You will receive a copy of the signed and dated written informed consent prior to your participation in the study.

Subject's Name (printed) \_\_\_\_\_

\_\_\_\_\_  
(Subject's Signature)

\_\_\_\_\_  
(Date)

## APPENDIX C. DEMOGRAPHIC FORM

**Attachment 6. Participant Information****1. Age**

- ☐ 18- 23      ☐ 30-35      ☐ 42- 47      ☐ 54-59  
☐ 24-29      ☐ 36-41      ☐ 48-53      ☐ 60-65      ☐ 65+

**2. Gender**

- ☐ Male      ☐ Female      ☐ -----

**3. Native language**

- ☐ English      ☐ Other (Please specify:-----)

**4. Education**

- ☐ Undergraduate student      ☐ College Graduate  
☐ Advanced Degree      ☐ Others (Please specify:-----)

**5. Please indicate what major and/or minor you are studying or have completed?**

- ☐ (Major: -----)  
☐ (Minor: -----)

**6. How comfortable are you using the following:****Computer:**

- ☐ Uncomfortable ☐ Slightly Uncomfortable ☐ Slightly Comfortable    ☐ Comfortable    ☐ Don't Use

**Tablets (iPads, Android Tablets):**

- ☐ Uncomfortable ☐ Slightly Uncomfortable ☐ Slightly Comfortable    ☐ Comfortable    ☐ Don't Use

**Smartphones:**

- ☐ Uncomfortable ☐ Slightly Uncomfortable ☐ Slightly Comfortable    ☐ Comfortable    ☐ Don't Use

**7. What kind of computer do you use?**

- ☐ Macintosh    ☐ PC (Dell, HP, IBM, Sony, Asus, Gateway, e-Machine, etc.)    ☐ Don't know

**8. How often do you use the following?****Web/Internet:**

- ☐ Never    ☐ Less than Monthly    ☐ Monthly    ☐ Weekly    ☐ Daily

**Microsoft Office (Word, Excel, Powerpoint, etc.):**

- ☐ Never    ☐ Less than Monthly    ☐ Monthly    ☐ Weekly    ☐ Daily

**Online Video Watching:**

- ☐ Never    ☐ Less than Monthly    ☐ Monthly    ☐ Weekly    ☐ Daily

**Social Media Network:**

- ☐ Never    ☐ Less than Monthly    ☐ Monthly    ☐ Weekly    ☐ Daily

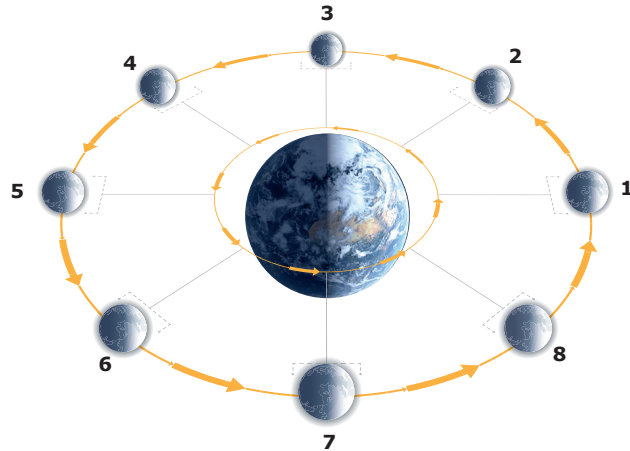
**Online News Websites:**

- ☐ Never    ☐ Less than Monthly    ☐ Monthly    ☐ Weekly    ☐ Daily

## APPENDIX D. PRE TEST

**Attachment 8.** Pre-Test Questionnaire

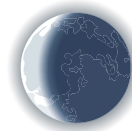
1. Please circle the moon's position for the **First Quarter** phase) ?



2. Approximately how many days does it take the moon to orbit the earth?

**26****27****28****29****30**

3. Which of the below is a quarter moon (Waning Crescent)?



4. Shade the Waxing Gibbous phases on the moon below?



## APPENDIX E. PRE TEST RESULTS

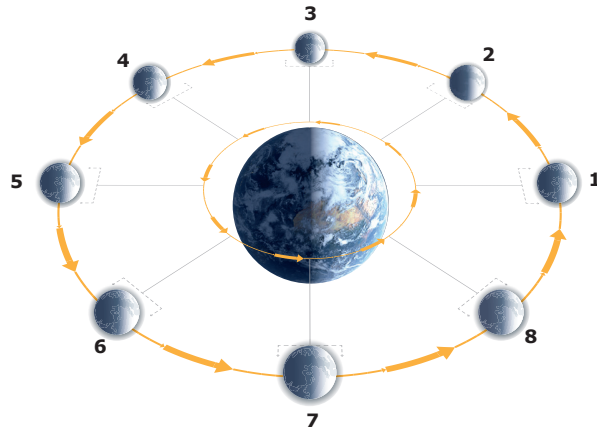
## The Pre Test Results

Participants Pre Test	Q1 Right Answers	Q2 Right Answers	Q3 Right Answers	Q4 Right Answers	Q1 Wrong Answers	Q2 Wrong Answers	Q3 Wrong Answers	Q4 Wrong Answers	Total Right Answers	Total Wrong Answers
Static Test 1			1		1	1		1	1	3
Static Test 2			1		1	1		1	1	3
Static Test 3			1		1	1		1	1	3
Static Test 4		1	1		1			1	2	2
Static Test 5			1		1	1		1	1	3
Static Test 6			1		1	1		1	1	3
Static Test 7	1	1	1					1	3	1
Static Test 8			1		1	1		1	1	3
Static Test 9			1		1	1		1	1	3
Static Test 10			1		1	1		1	1	3
Static Test 11		1	1		1			1	2	2
Static Test 12					1	1	1	1	0	4
Static Test 13	1		1			1		1	2	2
Static Test 14	1		1			1		1	2	2
Static Test 15		1	1		1			1	2	2
Animated Test 1			1		1	1		1	1	3
Animated Test 2			1		1	1		1	1	3
Animated Test 3	1					1	1	1	1	3
Animated Test 4	1		1			1		1	2	2
Animated Test 5	1		1			1		1	2	2
Animated Test 6	1		1			1		1	2	2
Animated Test 7			1	1	1	1			2	2
Animated Test 8			1		1	1		1	1	3
Animated Test 9			1		1	1		1	1	3
Animated Test 10					1	1	1	1	0	4
Animated Test 11			1		1	1		1	1	3
Animated Test 12	1		1	1		1			3	1
Animated Test 13			1		1	1		1	1	3
Animated Test 14			1		1	1		1	1	3
Animated Test 15					1	1	1	1	0	4
Group B - Static	3	4	14	0	12	11	1	15	21	39
Group A - Animated	5	0	12	2	10	15	3	13	19	41
Total	8	4	26	2	22	26	4	28	40	80

## APPENDIX F. POST TEST

**Attachment 9.** Post-Test Questionnaire

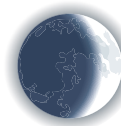
1. Please circle the moon's position for the Full Moon phase ?



2. At what degree is the moon when **Waxing Crescent**?

**25****35****45****60****90**

3. Which of the below is a Waxing Gibbous moon?



4. Shade the Waning Crescent moon phase on the moon below?



5. Do you have any feed back regarding this study?

---



---



---

## APPENDIX G. POST TEST RESULTS

## The Post Test Results

Participants Post Test	Q1 Right Answers	Q2 Right Answers	Q3 Right Answers	Q4 Right Answers	Q1 Wrong Answers	Q2 Wrong Answers	Q3 Wrong Answers	Q4 Wrong Answers	Total Right Answers	Total Wrong Answers
Static Test 1	1	1		1			1		3	1
Static Test 2	1	1	1					1	3	1
Static Test 3	1					1	1	1	1	3
Static Test 4	1		1	1		1			3	1
Static Test 5	1	1	1					1	3	1
Static Test 6	1	1	1	1					4	
Static Test 7	1	1	1					1	3	1
Static Test 8	1	1	1					1	3	1
Static Test 9	1		1			1		1	2	2
Static Test 10	1	1					1	1	2	2
Static Test 11			1		1	1		1	1	3
Static Test 12		1	1		1			1	2	2
Static Test 13	1					1	1	1	1	3
Static Test 14	1		1			1		1	2	2
Static Test 15	1	1	1	1					4	
Animated Test 1	1	1	1					1	3	1
Animated Test 2	1	1	1					1	3	1
Animated Test 3	1	1	1					1	3	1
Animated Test 4	1	1					1	1	2	2
Animated Test 5	1	1	1	1					4	
Animated Test 6	1	1	1					1	3	1
Animated Test 7	1		1			1		1	2	2
Animated Test 8	1		1			1		1	2	2
Animated Test 9				1	1	1	1		1	3
Animated Test 10					1	1	1	1		4
Animated Test 11	1	1	1					1	3	1
Animated Test 12				1	1	1	1		1	3
Animated Test 13		1			1		1	1	1	3
Animated Test 14	1	1					1	1	2	2
Animated Test 15		1			1		1	1	1	3
Group B - Static	13	9	11	4	2	6	4	11	37	23
Group A - Animated	10	10	8	3	5	5	7	12	31	29
Total	23	19	19	7	7	11	11	23	68	52



## APPENDIX H. PRE AND POST TEST RESULTS (Right Answers)

## The Pre Test Results

## The Post Test Results

Participants	Q1 Right Answers	Q2 Right Answers	Q3 Right Answers	Q4 Right Answers	Q1 Right Answers	Q2 Right Answers	Q3 Right Answers	Q4 Right Answers	Total Right Answers Pre-Test	Total Right Answers Post-Test
Static Test 1			1		1	1		1	1	3
Static Test 2			1		1	1	1		1	3
Static Test 3			1		1				1	1
Static Test 4		1	1		1		1	1	2	3
Static Test 5			1		1	1	1		1	3
Static Test 6			1		1	1	1	1	1	4
Static Test 7	1	1	1		1	1	1		3	3
Static Test 8			1		1	1	1		1	3
Static Test 9			1		1		1		1	2
Static Test 10			1		1	1			1	2
Static Test 11		1	1				1		2	1
Static Test 12						1	1		0	2
Static Test 13	1		1		1				2	1
Static Test 14	1		1		1		1		2	2
Static Test 15		1	1		1	1	1	1	2	4
Animated Test 1			1		1	1	1		1	3
Animated Test 2			1		1	1	1		1	3
Animated Test 3	1				1	1	1		1	3
Animated Test 4	1		1		1	1			2	2
Animated Test 5	1		1		1	1	1	1	2	4
Animated Test 6	1		1		1	1	1		2	3
Animated Test 7			1	1	1		1		2	2
Animated Test 8			1		1		1		1	2
Animated Test 9			1					1	1	1
Animated Test 10									0	0
Animated Test 11			1		1	1	1		1	3
Animated Test 12	1		1	1				1	3	1
Animated Test 13			1			1			1	1
Animated Test 14			1		1	1			1	2
Animated Test 15						1			0	1
Group B - Static	3	4	14	0	13	9	11	4	21	37
Group A - Animated	5	0	12	2	10	10	8	3	19	31
Total	8	4	26	2	23	19	19	7	40	68

## APPENDIX I. PARTICIPANT'S COMMENTS, POST-TEST GROUP A
















Participant	Comments
1	I think if you had a 360 representation of the moon phases I'd better understand each phase.
2	The animations were very well done! It increased my knowledge of the phases of the moon, which I previously didn't know anything about, If I were to watch this a few times, I am confident I could have mastered the subject completely.
3	I feel it was very informative and helped me understand the moon phases. However, more focus on waxing vs. waning.
4	Very helpful information. It was very interesting to watch.
5	The point of view from the Earth was helpful, when words were on the screen, I could remember them better (i.e., 27 days) – very engaging, the background music helped me focus on the animation.
6	I didn't really know anything about this but now that I've watched it I am more informed, easier than reading a book.
7	It would have been hard to understand the information clearly without the visuals. I definitely feel like I know more now than I did before.
8	Very simple, very easy to understand.
9	I thought it was really helpful and informational.
10	Video was informative, survey was simple and not too time-consuming.
11	Useful & informative. Helped me to understand a complex science subject because I was able to see and hear the information in action.
12	_____
13	Somewhat sure on answers, very informational infographic.
14	You were talking too fast during some of it, and it would be beneficial to speak clearer if possible!
15	Video was informative and easy to understand.

## APPENDIX J. PARTICIPANT'S COMMENTS, POST-TEST GROUP B
















Participant	Comments
1	I appreciated the radius /rotational visualization of the graphic. Had the phases of the moon been displayed in a horizontal or vertical format it would not have been as memorable; I would not have been able to remember the phases.
2	As a participant by being asked the first set of questions and then seeing the information graphic I was specifically looking at the graphic to see if I was right. I didn't think to look for new information, This may skew your data. Sorry
3	
4	Informative, easy to understand, representative of what I could expect from the topic, flowed easily.
5	Easy to understand topics, felt like memorization because I felt the survey is coming and I am not super excited about moon phases.
6	I felt it was a very effective learning tool. Visual learning has always been more effective for me. The info graphics were very clear, some illustrations try jamming too much info into 1 picture.
7	The infographics helped with understanding where the moon phases are. I am a visual learner so the infographics helped.
8	<b>The two different sets of moon might make it a little confusing.</b> Personally being Indian and also familiar with the lunar cycle ( I am not saying I knew it all) it helped to grasp the topic. The infographics are great otherwise.
9	It was helpful to see the infographic, but wasn't something that I necessarily remembered off the bet. Moon phases aren't particularly interesting to me so so they aren't something I would remember easily.
10	Well made infographic . Pictures were useful studying the infographic made me more confident in the material.
11	When reading the information I got a good understanding of how the waxing and waning can be identified as well as the different phases of the moon.
12	I found the infographic to be informative and it was laid out in away that was interesting and easy to follow.
13	I enjoyed the graphics it was an easy to read graphic.
14	Insightful, Interesting
15	Interesting study, I think the infographic was very informative (I should have taken more time to study it though)

## APPENDIX K. QUESTION FOUR ANSWERS
















## Group A (Animated Format) Post Test

Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7	Participant 8	Participant 9	Participant 10	Participant 11	Participant 12	Participant 13	Participant 14	Participant 15
														
















## Group B (Static Format) Post Test

Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7	Participant 8	Participant 9	Participant 10	Participant 11	Participant 12	Participant 13	Participant 14	Participant 15
														

## Group A (Animated Format) Pre Test

Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7	Participant 8	Participant 9	Participant 10	Participant 11	Participant 12	Participant 13	Participant 14	Participant 15
														

## Group B (Static Format) Pre Test

Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7	Participant 8	Participant 9	Participant 10	Participant 11	Participant 12	Participant 13	Participant 14	Participant 15
														

## APPENDIX L. DEMOGRAPHIC DATA (GROUP A)

Participant	Age Group	Gender	Native language	Education	Major	How comfortable in using		
						Computer	Tablets	Smartphones
1	18-23	Male	English	Undergraduate	Aerospace Engineering	Comfortable	Comfortable	Comfortable
2	18-23	Male	English	Undergraduate	Biology	Comfortable	Comfortable	Comfortable
3	18-23	Female	English	Undergraduate	Biology	Comfortable	Comfortable	Comfortable
4	18-23	Female	English	Undergraduate	Animal Science	Comfortable	Slightly Comfortable	Comfortable
5	18-23	Female	English	Undergraduate	Biology	Comfortable	Comfortable	Comfortable
6	18-23	Female	English	Undergraduate	Animal Science	Comfortable	Comfortable	Comfortable
7	18-23	Female	English	Undergraduate	Animal Science	Comfortable	Slightly Comfortable	Comfortable
8	18-23	Male	English	High School Graduate	High School Graduate	Comfortable	Comfortable	Comfortable
9	18-23	Male	English	High School Graduate	High School Graduate	Comfortable	Comfortable	Comfortable
10	18-23	Female	English	Undergraduate	Pre-Health Program	Comfortable	Comfortable	Comfortable
11	18-23	Female	English	Undergraduate	Agriculture Business	Comfortable	Comfortable	Comfortable
12	18-23	Female	English	Undergraduate	Animal Science	Comfortable	Slightly Comfortable	Slightly Comfortable
13	18-23	Male	English	Undergraduate	Agriculture Business	Comfortable	Comfortable	Comfortable
14	18-23	Female	English	Undergraduate	Animal Science	Comfortable	Comfortable	Comfortable
15	18-23	Female	English	Undergraduate	Kinesiology	Comfortable	Comfortable	Comfortable

Participant	Computer type use	How often using the following							
		Web /Internet	Microsoft office	Online video watching	Social Media	Online News Websites	Email	Print Magazines	News Papers
1	PC	Daily	Weekly	Daily	Daily	Weekly	Daily	Monthly	Weekly
2	PC	Daily	Weekly	Daily	Daily	Weekly	Daily	Weekly	Less than Monthly
3	PC	Daily	Weekly	Daily	Daily	Weekly	Daily	Less than Monthly	Never
4	Mac	Daily	Weekly	Daily	Daily	Monthly	Daily	Less than Monthly	Less than Monthly
5	PC	Daily	Daily	Daily	Daily	Daily	Daily	Weekly	Monthly
6	Mac	Daily	Weekly	Less than Monthly	Daily	Daily	Daily	Monthly	Less than Monthly
7	Mac	Daily	Daily	Weekly	Daily	Daily	Daily	Monthly	Never
8	Mac/ PC	Weekly	Monthly	Weekly	Daily	Monthly	Weekly	Monthly	Monthly
9	PC	Weekly	Monthly	Weekly	Daily	Weekly	Weekly	Less than Monthly	Less than Monthly
10	Mac	Daily	Weekly	Weekly	Daily	Weekly	Daily	Less than Monthly	Less than Monthly
11	Mac	Daily	Daily	Daily	Daily	Daily	Daily	Weekly	Weekly
12	Mac	Daily	Daily	Daily	Daily	Never	Daily	Less than Monthly	Never
13	Mac	Daily	Daily	Weekly	Daily	Weekly	Daily	Weekly	Weekly
14	PC	Daily	Daily	Daily	Daily	Weekly	Daily	Less than Monthly	Less than Monthly
15	Mac	Daily	Daily	Daily	Daily	Weekly	Daily	Weekly	Weekly

## APPENDIX M. DEMOGRAPHIC DATA (GROUP B)

Participant	Age Group	Gender	Native language	Education	Major	How comfortable in using		
						Computer	Tablets	Smartphones
1	36-41	Female	English	Advanced Degree	Graphic Design	Comfortable	Comfortable	Comfortable
2	24-29	Female	English	Advanced Degree	Graphic Design	Comfortable	Comfortable	Comfortable
3	18-23	Male	English	Undergraduate	Software Engineering	Comfortable	Comfortable	Comfortable
4	18-23	Male	Spanish	Undergraduate	Micro Biology	Comfortable	Comfortable	Comfortable
5	18-23	Male	English	Undergraduate	Computer Science	Comfortable	Comfortable	Comfortable
6	24-29	Male	English	Undergraduate	Psychology	Slightly Comfortable	Comfortable	Slightly Comfortable
7	18-23	Male	English	Undergraduate	Agriculture Business	Comfortable	Slightly Comfortable	Comfortable
8	24-29	Male	English	College Graduate	Graphic Design	Comfortable	Comfortable	Comfortable
9	18-23	Female	English	Undergraduate	Graphic Design	Comfortable	Comfortable	Comfortable
10	18-23	Male	English	Undergraduate	Animal Science	Slightly Comfortable	Slightly Comfortable	Comfortable
11	18-23	Male	English	Undergraduate	Animal Science	Slightly Comfortable	Slightly Comfortable	Slightly Comfortable
12	18-23	Female	English	Undergraduate	Kinesiology	Comfortable	Comfortable	Comfortable
13	18-23	Male	English	Undergraduate	Food Science	Comfortable	Comfortable	Comfortable
14	18-23	Male	English	Undergraduate	Animal Ecology	Comfortable	Comfortable	Comfortable
15	18-23	Male	English	Undergraduate	Computer Science	Comfortable	Comfortable	Comfortable

[illegible]



## BIBLIOGRAPHY

- Armstrong, T. (2009). *Multiple intelligences in the classroom*. Ascd.
- Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. *The psychology of learning and motivation*, 2, 89-195.
- Aviation Instructor's Handbook. US Dept of Transportation, Federal Aviation Administration 2008.
- Advanced data visualization guide: How visualizing data can boost BI. (n.d.). Retrieved December 20, 2015, from <http://searchbusinessanalytics.techtarget.com/essentialguide/Advanced-data-visualization-guide-How-visualizing-data-can-boost-BI>
- Antonio Farach on Behance. (n.d.). Retrieved January 9, 2016, from <https://www.behance.net/antoniofarachd05c>
- Bateman, S., Mandryk, R. L., Gutwin, C., Genest, A., McDine, D., & Brooks, C. (2010, April). Useful junk?: the effects of visual embellishment on comprehension and memorability of charts. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 2573-2582). ACM.
- Cairo, A. (2012). *The Functional Art: An introduction to information graphics and visualization*. New Riders.
- Chomsky, N. (2002). *Media control: The spectacular achievements of propaganda* (Vol. 7). Seven Stories Press.
- ChanLin, L. J. (1998). Animation to teach students of different knowledge levels. *Journal of Instructional Psychology*.
- Denton, C. (1992). *Graphics for visual communication*. William C Brown Pub.
- Davidson, Rosemary. "Three investigations in which students present their results in infographics." *The Science Teacher* (2014): 34-39.
- Few, S. (2004). Tapping the power of visual perception. *Visual Business Intelligence Newsletter*.
- Gonzalez, H. B., & Kuenzi, J. J. (2012, August). Science, technology, engineering, and mathematics (STEM) education: *A primer*. Congressional Research Service, Library of Congress.
- Gambrell, L. B., & Jawitz, P. B. (1993). Mental imagery, text illustrations, and children's story comprehension and recall. *Reading Research Quarterly*, 265-276.

Hegarty, M., Kriz, S., & Cate, C. (2003). The roles of mental animations and external animations in understanding mechanical systems. *Cognition and instruction*, 21(4), 209-249.

How Hydraulic Fracturing Works. (2013, April 1). Retrieved 2016, from <http://education.nationalgeographic.org/media/how-hydraulic-fracturing-works/>

*Joint economic committee-Republicans (2010). FIRST LOOK, AMERICA'S NEW HEALTH CARE SYSTEM REVEALED. A Press Release.*

Katz, J. (2012). Designing information: *Human factors and common sense in information design*. John Wiley & Sons.

Lidwell, W., Holden, K., & Butler, J. (2010). Universal principles of design, revised and updated: *125 ways to enhance usability, influence perception, increase appeal, make better design decisions, and teach through design*. Rockport Pub.

Lankow, J., Ritchie, J., & Crooks, R. (2012). *Infographics: The power of visual storytelling*. John Wiley & Sons.

Lunar Cycles. (n.d.). Retrieved April 17, 2016, from <http://astro.unl.edu/classaction/images/lunarcycles/lunarcycles.html>

Meirelles, I. (2013). *Design for Information: An Introduction to the Histories, Theories, and Best Practices Behind Effective Information Visualizations*. Rockport publishers.

*Memory Retention and the Forgetting Curve Infographic* - e-Learning Infographics. (2014, March 26). Retrieved June 15, 2015, from <http://elearninginfographics.com/memory-retention-and-the-forgetting-curve-infographic/>

Murphy, C. (2011). Why games work and the science of learning. In *Interservice, Interagency Training, Simulations, and Education Conference* (pp. 260-272).

Mayer, R. E., Hegarty, M., Mayer, S., & Campbell, J. (2005). When static media promote active learning: annotated illustrations versus narrated animations in multimedia instruction. *Journal of Experimental Psychology: Applied*, 11(4), 256.

Narayanan, N. H., & Hegarty, M. (2002). Multimedia design for communication of dynamic information. *International journal of human-computer studies*, 57(4), 279-315.

Ostwald-Kowald, T. (n.d.). Understanding Your Student's Learning Style: The Theory of Multiple Intelligences. Retrieved July 10, 2015, from <http://www.connectionsacademy.com/blog/posts/2013-01-18/Understanding-Your-Student-s-Learning-Style-The-Theory-of-Multiple-Intelligences.aspx>

Park, O. C., & Gittelman, S. S. (1992). Selective use of animation and feedback in computer-based instruction. *Educational Technology Research and Development*, 40(4), 27-38.

Peters, D. (2013). *Interface design for learning: Design strategies for learning experiences*. Pearson Education.

Portfolio of the Week - Raúl Camañas - Visualoop. (2015, July 13). Retrieved January 9, 2016, from <http://visualoop.com/blog/33743/portfolio-of-the-week-raul-camanas>

Spencer, M., Allina, B., & Shrestha, R. (2012, August 17). Full STEAM ahead: As STEM discussions heat up, there is a growing desire to add an 'A' for art - Pittsburgh Business Times. Retrieved June 10, 2015, from <http://www.bizjournals.com/pittsburgh/print-edition/2012/08/17/full-steam-ahead-as-stem-discussions.html?page=all>

Traditional Oman Dress (men) - Visualoop. (n.d.). Retrieved January 9, 2016, from <http://visualoop.com/infographics/traditional-oman-dress-men>

Kang, S. (2005). Framework for information design in the information age. *Int J Humanit*, 3(2), 215-219.

Tversky, B., Morrison, J. B., & Betrancourt, M. (2002). Animation: can it facilitate?. *International journal of human-computer studies*, 57(4), 247-262.

Tufte, E. R. (2006). *Beautiful Evidence*. Graphics Press LLC.

Tufte, E. R. (1997). *Visual explanation. Images and Quantities, Evidence and Narrative*, Cheshire, Connecticut. Graphics Press.

Train The Trainer Guide. (n.d.). Retrieved June 16, 2015, from <http://www.au.af.mil/au/awc/awcgate/edref/traingde.htm> A United States Government document

“Train the Trainer Guide”. The US Air Force, Training Systems Division. Authors unknown. 2004.

Ware, C. (2012). *Information visualization: perception for design*. Morgan Kaufmann, Elsevier.